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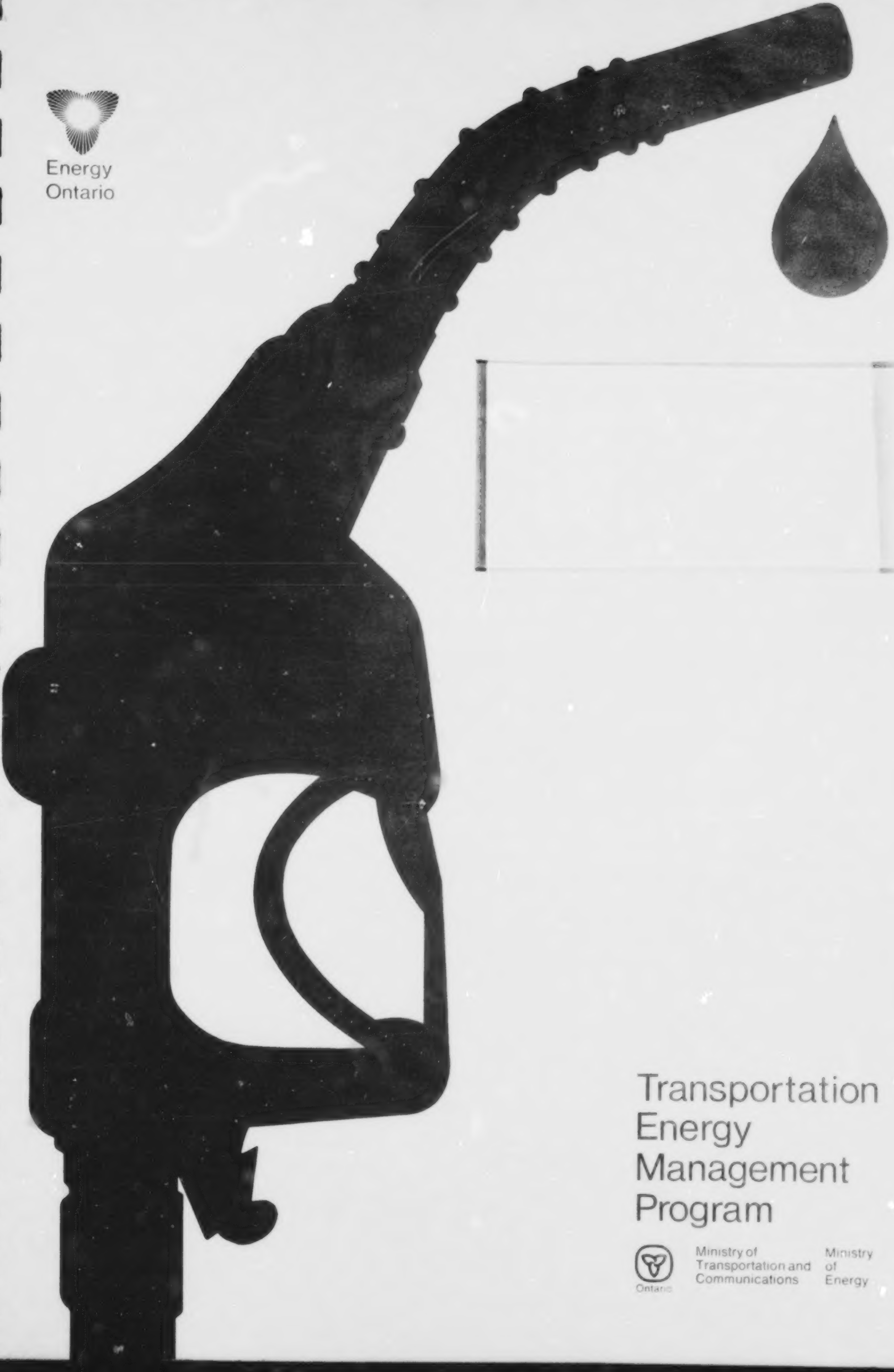

Transportation Energy Management Program

Ontario

Ministry of
Transportation and
Communications

Ministry
of
Energy

AF-85-01

PROGRESS REPORT
THE OTTAWA-CARLETON REGIONAL TRANSIT
PROPANE BUS DEMONSTRATION

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PROPANE BUS DEMONSTRATION

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D.M. Allan, Deputy Minister

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April 1985

EXECUTIVE SUMMARY

A project to demonstrate the use of propane in a transit application was initiated in late 1982 at the Ottawa-Carleton Regional Transit Commission (OC Transpo). Funding for the project was supplied by the Federal Department of Energy, Mines and Resources, the Ontario Ministry of Energy and OC Transpo. The project is being managed by the Ontario Ministry of Transportation and Communications and OC Transpo. The total project cost was estimated to be 1.34M and the project was to be completed by the Fall of 1986.

The demonstration was divided into two phases. Phase I work involved the selection of a propane engine manufacturer, development work to adapt the engine to a standard GMC transit bus, a GO/NO GO decision based upon a track performance evaluation between a propane and diesel powered GMC bus, and limited service evaluation. Engine dynamometer testing of the propane and standard 2-stroke GMC diesel engines at UTDC was also initiated at this time.

Phase II included the purchase of 15 propane and one 4-stroke diesel engine, the conversion of fifteen buses to propane and one to IVECO diesel, installation of fueling facilities, modification of maintenance facilities for servicing propane vehicles and the revenue operation of the buses over at least one year.

As of March 31, 1985 the first seven buses had been converted to propane. A "GO" decision had been made at the March 27/84 Steering Committee meeting and the official opening of the program took place at the November 21/84 CUTA conference in Ottawa. The installation of propane storage and fueling equipment, the conversion of maintenance facilities to handle propane vehicles and the development and implementation of a data collection/collation system for the converted buses is under way.

Based upon test data and current propane and diesel fuel prices in Ottawa, it is estimated that the propane bus fuel cost is between $4000 and $5000 less per year per bus than that of the 6V-71 diesel powered bus.

With the closing out of the Provincial/Federal CREDA agreement on March 31, 1985 a revised revenue demonstration and information gathering program are proposed. The proposed program would run one extra year, to be completed in August 1987 and would document the operation of the entire propane bus fleet in detail over a two year period.

The remainder of the program is by far the most important since most of the capital appropriations have been spent and the hardware put into place (buses plus infrastructure). The demonstration phase which is about to begin will yield valuable fuel consumption, reliability and maintenance information as well as public and driver impressions of the buses relative to standard diesel-powered vehicles.

TABLE OF CONTENTS

EXECUTIVE SUMMARY ii

1.0 PROPANE ENGINE DEVELOPMENT 1

2.0 PHASE I: PRE-DEMONSTRATION EVALUATION 2

3.0 INCLUSION OF THE FOUR-STROKE DIESEL ENGINE 3

4.0 UTDC ENGINE TESTING 4

5.0 PUBLIC RELATIONS PROGRAM 5

6.0 PROGRESS TO DATE 6

7.0 FUTURE PLANS 7

FIGURES AND TABLES

APPENDIX A - Quarterly Reports

APPENDIX B - Technical Reports

APPENDIX C - UTDC Diesel Engine Test Report

APPENDIX D - Minutes of Meetings

APPENDIX E - CUTA Presentations

APPENDIX F - Press Kit

APPENDIX G - Contract

APPENDIX H - Demonstration Proposal

1.0 PROPANE ENGINE DEVELOPMENT

The unavailability of a North American manufactured propane bus engine resulted in the selection of the Swiss company "DERECO" to supply the required power plant. The propane engine is designated the 8220.02 and is a converted IVECO (FIAT) in-line six diesel engine, optimized to run on Canadian-quality propane. The compression ratio (reduced to 10.9:1), spark timing, fuel mixture, the engine mounts, flywheel, flywheel housing, accessory mounts and exhaust system were modified. The biggest change required however, was the direction of engine rotation which had to be reversed on the propane engine to match the 6V-71 diesel. Rotation reversal necessitated changes to the camshaft, water pump, alternator, starter, air compressor and cooling fan.

Early cooling problems were encountered, but these were rectified by the addition of an eight-blade fan (in place of the six-blade) and an increase in cooling system pressure (from 4 to 6 psig). Details on the engine and fuel tank installation in the bus are provided in the first presentation "Fuel Economy of Canada's City Buses" in Appendix E. Initial propane engine running and evaluation are documented in Technical Report #1 (Appendix B).

2.0 PHASE I: PRE-DEMONSTRATION EVALUATION

In order to verify that the proposed propane engine delivered acceptable performance, driveability and fuel economy, a track test program was devised. This involved the running of one propane bus and one standard diesel bus through a series of modified Advanced Design Bus (ADB*) cycles. Fuel consumption was determined for each bus on a minimum of five runs each and the "Fuel Utilization Ratio" (FUR), computed by dividing the volumetric propane consumption per cycle by that for the diesel was determined.

Details of this test, which provided information upon which the GO/NO GO decision was based, are included in the program contract, Appendix G. The maximum FUR was specified in the contract at 1.80. The propane bus program was given the go-ahead after the propane-powered bus achieved a 1.70 FUR relative to the 6V-71 diesel-powered bus. The testing is described in Appendix B, Technical Report #2.

Additional information which supported the GO/NO GO decision included the measurement of acceleration time for each bus. This testing showed that the performance of the propane bus was very close to that of the standard GMC Bus. (Fig. 1)

Substantial road testing was also performed to confirm driveability and ensure that all accessories and engine related systems were operating properly under a variety of operating conditions.

Following the decision to go ahead with the program, the remaining fourteen propane engines were ordered from DERECO along with fuel tanks and other hardware from local suppliers, as well as the initiation of negotiations with propane suppliers with regard to an on-site fueling facility. In addition OC Transpo mechanics were trained in propane equipment installation (S6A) and inspection (S6B), the maintenance facilities were inspected for suitability for propane bus servicing and development of the program information gathering and processing infrastructure was begun.

*The ADB cycle was developed by Booze-Allen & Hamilton to approximate a typical trnsit bus duty cycle covering urban, suburban and highway operation.

3.0 INCLUSION OF THE FOUR-STROKE DIESEL ENGINE

In order to provide valuable information with regard to differences between North American 2-stroke diesels and European 4-stroke diesels, as well as between 4-stroke diesel and propane engines (of the same block), a decision was made early in the program to include one IVECO 4-stroke diesel engine with the same basic block as the propane engine in the demonstration.

The DERECO propane engine used in this demonstration is different from the 6V-71 diesel not only because it burns a different fuel but because of many additional fundamental design differences as well. For example the 6V-71 incorporates a 2-stroke cycle whereas the DERECO propane engine operates on a 4-stroke cycle. The 6V-71 has a positive-displacement blower required to scavenge the cylinders, unlike the naturally aspirated propane engine. The blower absorbs a percentage of engine power. In addition the 2-stroke cycle is inherently less efficient than that of the 4-stroke engine. For these reasons the 2-stroke engine typically provides somewhat greater specific fuel consumption compared to a 4-stroke of the same mechanical specifications (i.e. bore, stroke, compression ratio, etc.) on a given fuel.

Plans for this engine included dynamometer testing at UTDC to be followed by installation into an OC Transpo standard GMC bus for road comparison with the rest of the bus fleet. Testing of the 4-stroke diesel at UTDC has recently been completed.

4.0 UTDC ENGINE TESTING

In order to obtain accurate performance data for each of the engines involved in the test program, supplementary tests, performed at UTDC were planned. These tests, initially involving the 6V-71 diesel and DERECO propane engines, were incorporated into the demonstration program and included full engine mapping as well as full ADB cycle simulation and two ADB components. Additional contracts between UTDC and the Ministry of Transportation and Communications (MTC) were placed to include the IVECO diesel engine in the program and additional tests on all 3 engines (see Table 1).

The UTDC facility consists of an electrical, computer controlled engine dynamometer which enables full computer control of the engine including simulated cycles such as the modified ADB cycles followed during the GO/NO GO test.

All results to date indicate that the UTDC facility is quite capable of providing excellent fuel consumption and power data under both mapping and cycling modes of operation. To date, all testing has been completed on the 6V-71 and IVECO diesel engines. The balance of the work (on the DERECO propane engine) is scheduled for completion by the end of April 1985. The UTDC report on the 6V-71 testing is included in Appendix C.

5.0 PUBLIC RELATIONS PROGRAM

The official opening of the OC Transpo Propane Bus Demonstration was held on November 21, 1984 during the fall CUTA Conference at the Skyline Hotel in Ottawa. Short speeches were given by Mr. A. Haydon for OC Transpo, Mr. J. McDermid for Energy, Mines and Resources, Canada, Mr. R. Higgin for the Ministry of Energy, Ontario, and Mr. M. Kells for Ministry of Transportation and Communications, Ontario. The above presentation was followed by a ribbon-cutting ceremony next to the first propane bus by interested persons.

Technical papers were then presented by OC Transpo personnel. These have been reproduced in Appendix E for reference.

A press kit was also released including a press release, background information sheets and a pamphlet (see Appendix F).

6.0 PROGRESS TO DATE

As of March 31, 1985 most of the work required to put the propane bus fleet into operation has been performed. The propane engine has been selected and re-engineered to match the installation requirements of the GMC bus. The engines have been performance-tested and a total of 17 have been ordered and delivered (15 for installation plus two spares). Seven of the 15 buses have been converted by OC Transpo.

The vehicle fuel tanks and fuel delivery systems have been designed and delivered. OC Transpo mechanics are equipped to install engines and fuel systems as well as maintain them under revenue service conditions.

The on-site fuel storage and delivery systems are currently being installed. A contract has been signed with the propane supplier for propane fuel at an attractive price which provides a significant fuel cost saving over the diesel bus.

The bus maintenance and fuel consumption data acquisition system is being assembled and will be on line soon, enabling accurate monitoring of the propane buses relative to the diesel fleet.

Maintenance facilities at the St. Laurent garage have been carefully assessed and significant upgrading is planned to ensure the safe storage and maintenance of the propane vehicles.

Total funding to date from Energy Mines and Resources and the Ministry of Energy under the former CREDA agreement totals $807,422. Figure 2 compares actual spending to the original projected program cash flow. The gap between projected and actual reflects a six-month initial delay in the program due to a number of minor startup problems on the first bus.

7.0 FUTURE PLANS

Due to the termination of the CREDA agreement which has supported this program to date, the original contract signed November 15, 1983 must be replaced by a new agreement under the new "Ener Demo" program between EMR and the Ontario Ministry of Energy.

The work to be completed under the new contract comprises the completion of some tasks left incomplete due to the early termination of the original contract and the running of the fifteen propane buses in revenue service for two years.

Work which must be completed includes the upgrading of maintenance facilities with the installation of explosion-proof equipment, venting and sensor alarm systems. The remaining seven buses must be converted to propane power also and the on-site refueling facility completed.

During the demonstration, fuel consumption and maintenance data will be continually collected and assessed. This information will be of primary importance in the final assessment of the suitability of propane fuel in transit applications.

Public and driver surveys will be conducted and assessed to determine public attitudes towards utilizing propane buses in a typical transit operation.

The proposed two-year follow-up program is included in Appendix H. Total projected costs amount to $495,000, $270,000 of which will be contributed by EMR and the Ministry of Energy under separate contracts ($135,000 from each).

Deliverables of the proposed program are as follows:

1. Technical Reports and Final Reports providing information on the operating experience, capital expenditures and operating costs of:

    (a) the 15 propane bus fleet
    (b) the 4-stroke diesel bus performance relative to the 6V-71 and propane-powered buses
    (c) the propane fuel storage and delivery facility
    (d) the maintenance facility modifications required to safely handle propane buses.

2. A survey report documenting the attitude of the public toward the propane bus system.
3. Publications in reputable related publications which will be of value to other transit bus operators.
4. Publicity in the form of articles, seminars and displays.
5. Special reports dealing with other issues (technical/economic/safety) related to propane use in transit applications.
6. Guidelines by which transit properties may continue to manage and expand their propane bus fleets (OC Transpo included).

Figure 1 COMPARISON OF ACCELERATION OF PROPANE AND DIESEL BUS

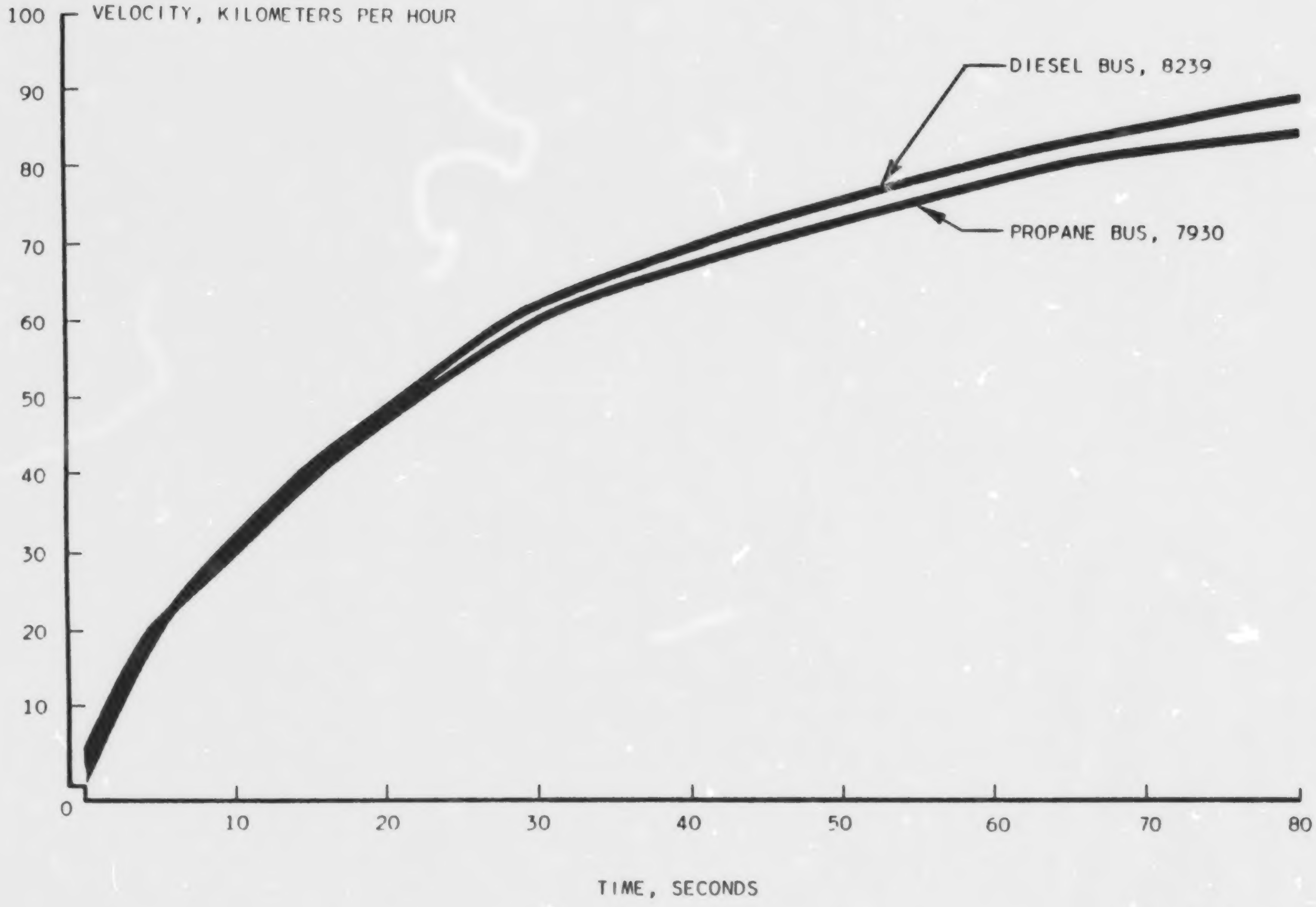


Figure 2 - Revised Program Cash Flow

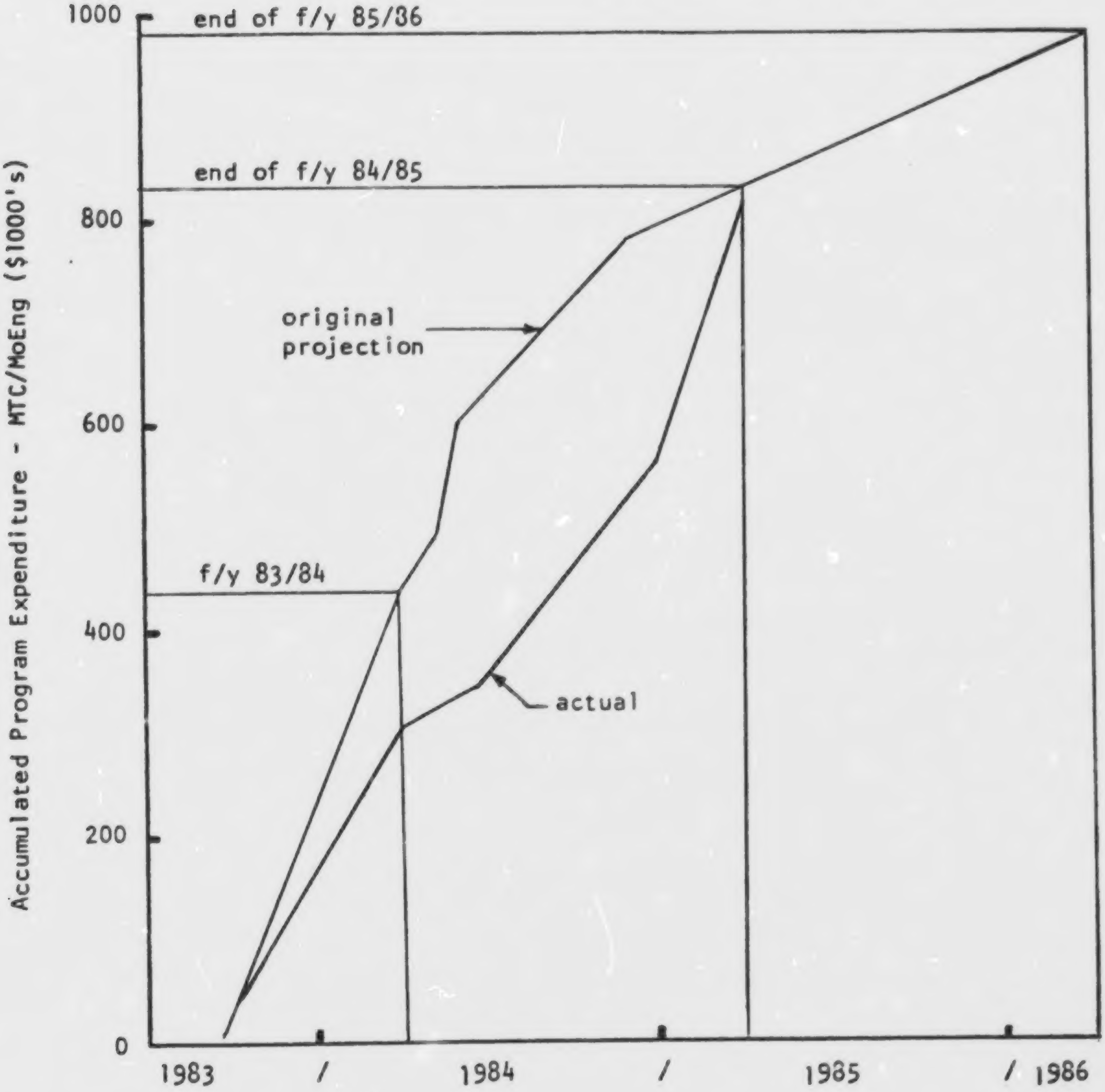


TABLE 1 - UTDC ENGINE DYNO TEST PROGRAM

TEST DETAILS	DDA 6V-71 DIESEL	IVECO 82220.02 PROPANE	IVECO 8220.02 DIESEL
Engine Mapping	OCT	OCT	MTC III
Full ADB Cycle 27,700 lbs	OCT	OCT	MTC III
CBD - ADB Component - 27,700 lbs	OCT	OCT	MTC III
Arterial ADB Component - 27,700 lbs	OCT	OCT	MTC III
Commuter ADB Component - 27,700 lbs.	MTC II	MTC II	MTC III
Full ADB Cycle - 33,500 lbs	MTC II	MTC II	MTC III
Full ADB Cycle - 21,575 lbs	MTC II	MTC II	MTC III

OCT - OC Transpo contract with UTDC

MTC II - MTC contract with UTDC, Phase II

MTC III - MTC contract with UTDC, Phase III

APPENDIX A

QUARTERLY REPORTS

APPENDIX A - QUARTERLY REPORTS

OC TRANSPO PROPANE BUS DEMONSTRATION

QUARTERLY REPORT #1: MARCH 18, 1984

1. SUMMARY OF STATUS OF DEMONSTRATION

1.1 Contracts

MTC: The contract between MTC and OC Transpo dated November 15, 1983 provides for demonstrations to August 1986 at a total cost of $1,340,340; $975,000 of which is budgeted by MTC.

Dereco: Contracts were placed with Dereco for:

i. the one-time engineering to ensure compatibility of their engines with the GM bus and transmission system ($75,000 Cdn.)
ii. the supply of 15 propane engines and one diesel engine (about $294,000 Cdn.).

Expenditures beyond those for one time engineering costs, the diesel engine and first propane engine already received await the GO/NO GO decision of the Steering Committee.

Westeel-Rosco: Fabrication of one in-vehicle propane fuel system was purchased from Westeel- Rosco to OC Transpo specifications of contract and warranties. The remaining 14 systems will be executed after the GO/NO GO decision.

UTDC: A contract in the amount of $96,300 has been executed with UTDC for the comparative testing of a GM 6V-71 engine and the Dereco 8220-02 propane engine.

Consultants: A contract for consulting and reporting services for the period of the demonstration to a total of $70,000 was placed with the R.F. Webb Corporation of Ottawa.

1.2 Budget and Commitments

The annual budget for the demonstration summarized in Exhibit 1 is unchanged in total from the contract sum.

Expenditures to March 18, 1984 totalled $120,497 principally for purchase of one-time engineering,one diesel and one propane engine from Dereco, design, fabrication and installation of the fuelling system in the propane bus.

Expenditures to March 31, 1984 which will be billed to MTC total $312,557 which includes purchase of 14 propane engines and contract to Webb.

Expenditures to March 31, 1984 charged to OC Transpo total $24,400 for project management and secretarial costs.

Advice is sought on the scheduling of expenditures planned for 1984/6 in view of the termination date of the CREDA agreement between Ontario and the federal government.

1.3 Organization and Schedule

The revised schedule for the demonstration is summarized in Exhibit 2.

The organization for the demonstration is shown in Exhibit 3.

The OC Transpo strategy is to bring the propane buses into the current operating system to test them under realistic operating conditions and not to isolate the propane fleet. The objective is to end the demonstration in a position to continue and expand the propane fleet.

Repowering and servicing of the buses will therefore be undertaken by the current maintenance group, trained in propane safety and equipped with new tools and instrumentation appropriate to propane. The fabrication of the propane fuel tanks in each vehicle is to be contracted out to Westeel-Rosco to a design already approved by OC Transpo and the Fuels Safety Branch of the Ontario Ministry of Consumer and Commercial Relations. Similarly, the fabrication of brackets, lines and other items needed to interface the bus/fuel system/engine in each of the 14 conversions planned will be contracted out, using OC Transpo-approved designs taken from the experience with the first conversion.

In service, the propane buses will be comingled with the existing fleet to provide data and to permit measurement of public response throughout the system. Driver and inspector training will be provided broadly, rather than the training of only specialized drivers for the propane buses.

It will be necessary to segregate certain facilities for maximum safety and minimum cost. A manual on propane safety in the fleet will be available in May to guide decisions on training, facility changes and equipment. Until designs are complete and a decision is made on the installation of a new fixed fuelling system, OC Transpo plans to have the propane buses fuelled on-site from a propane tanker: the refuelling service to be provided by the fuel supplier, provided that the final economics justify this method. The interim fuel supply by visiting tanker will provide the opportunity to train OC Transpo staff while construction of the permanent facility is undertaken.

The strategy for exposing the total operation to propane best fits the existing OC Transpo operation. As shown in Exhibit 3, the propane integration will be managed by the project manager, Mr. W. Jenkins of the Equipment Department, essentially on a full time basis with assistance provided by the current engineering and administration staff and by specialized consultants, including the engine supplier Dereco and the project reporter, Webb.

1.4 Work Completed to Date

1.4.1 Engine Development and Testing

The dummy engine ordered indicated a need to develop an interface to the GM transmission to reverse engine rotation. Subsequently, Dereco recommended change of engine from Saurer to Iveco (Fiat group). New engine and transmission interface work was completed under budget (110,000 Swiss Francs vs. 120,000 budgeted). A second dummy (of Iveco engine) was installed to resolve fitting the engine into the vehicle, interfacing with fan and starter, alternator and fuel lines and tank system. Concern over cooling system and starter led to selection of Flyer fan, fan blade changes and design of special starter (Bosch).

1.4.2 Fuel System

The original design of vehicle fuel tank system could not provide the capacity required. A new manifolded tank system was designed by Westeel-Rosco and installed in a diesel bus, tested for serviceability and accepted as a safe design for future buses by OC Transpo and the Safety Branch of the Ministry of Consumer and Commercial Relations. Shielding against road hazards (manhole covers, rocks) will be incorporated in the future buses and the #1 propane bus reworked July 1984.

1.4.3 Preliminary Vehicle Testing

The first propane engine and components arrived early December 1983 and were tested in the cradle then installed in the bus and connected to the fuel system. The vehicle was tested on the dynamometer and briefly operated on the highway in a demonstration for MTC and Department of Energy representatives on December 13, 1983.

Subsequent operations of the propane bus indicated insufficient power, overheating, and other minor problems. Changes were made in the vapourizer and carburetor. A fan clutch and Flyer fan were installed, together with a new starter.

Comparative tests of the propane engine and bus and a "typical diesel" engine/bus indicated that the propane engine met the OC Transpo specifications on the dynamometer and gave a power output equal to the average of recent acquisitions.

Simulated service tests on a city run and a suburban run with the propane bus and the "typical diesel" showed no difference in route timing for the two buses. A technical report on these tests was prepared (Technical Report #1).

1.4.4 Acceptance Tests

The acceptance tests and criteria described in the contract (Schedule C) were conducted at the Land Engineering Test Establishment (LETE) of DND over the period March 5-14, rather than at Blainville as planned, and tests involved only the propane bus and the GM "typical diesel". The results are contained in Technical Report #2 and can be summarized thus:

i. Mean fuel consumption over the ADB cycles:

Diesel bus	53.65 L/100km
Propane bus	91.40 L/100km

ii. The Fuel Utilization Ratio* over the test track in the ADB cycles was calculated at 1.70 . The required maximum for acceptance was set at 1.80 in the contract.
(*FUR is the mean fuel consumption of the propane-powered bus - L/100km divided by that of the 6V-71 diesel-powered bus L/100km).
It is noted that the average diesel fuel consumption of the total fleet in service at OC Transpo in 1983 was reported as 64.2 L/100km: new GM buses average 51 to 52L/100km.

iii. Performance over the ADB cycle was well within the specified limits, with an excellent level of consistency on each phase of each cycle, and between cycles. This consistency resulted in the minimum number of test cycles being performed on each bus.

iv. In-service Tests. The 30 day test in service is incomplete but 4 days of operations have been attained without problems. This short period of testing with earlier testing and demonstration runs is sufficient to make the GO/NO GO decision.

1.5 Key Meetings and Liaison

A working relationship has been established between OC Transpo and MTC staff, which has resolved certain scheduling and test issues. Two meetings were held between MTC and Energy department representatives (Ottawa and Toronto) in the period. The first meeting of the Steering Committee was held in Ottawa on March 2 when details of the project schedule and budget were resolved and a technical progress report was provided, concluding with a short tour in the propane bus.

The engine supplier, Dereco, provided prompt and satisfactory response to enquiries and 4 visits to Ottawa were made by their project engineer to review requirements, and provide assistance in the installation and testing of the propane engine. Similar prompt service and design changes were provided by the fuel storage system supplier, Westeel-Rosco.

2. SCHEDULE CHANGES

The unexpected need for the design, fabrication and testing of the adapter for reverse rotation has delayed the GO/NO GO tests and initiation of series production and testing of the 15 vehicle fleet. Other problems of the type expected have been promptly solved. Extreme weather conditions delayed track testing. The new schedule for the demonstration provides for accelerated delivery (facilitated by advanced ordering and OC Transpo commitment to long delivery items); it is realistic, but provides only 21 months of revenue service for the total fleet to the contract conclusion date of August 31, 1984 versus 25 months originally planned. This curtailment of the test period is not expected to seriously affect the quality of data or the decision which can be made on future bus conversions and may be preferable to an extension much beyond the CREDA funding cut-off date.

3. AN INTERIM RECOMMENDATION

The Project Manager and the Technical Consultant recommend acceptance of the limited test data as a basis for a positive decision by the Steering Committee on the procurement of the remaining engines and continuation of the demonstration program.

4. OTHER MATTERS

Should the Steering Committee choose a "GO" decision for further procurement and testing, consideration should be given to the form and timing of announcements. The week of May 22nd - the occasion of the VIth International Alcohol Fuels Symposium in Ottawa - is a possible date for announcements and a public demonstration of the propane bus.

EXHIBIT 1: BUDGET (AND COMMITMENTS TO MARCH 31, 1984)

P.O. PURCHASE ORDER

	1983/4		1984/5		1985/6		TOTAL	
	MTC Charged	OC Transpo	MTC Charged	OC Transpo	MTC Charged	OC Transpo	MTC Charged	OC Transpo
1. One time engine development contract *	40,043						64,033	
2. P.O. propane engines Dereco	202,882		64,400				267,282	
3. P.O. diesel engine, Dereco	17,732						17,732	
4. Other conversion equipment, tanks	3,000		79,000				82,000	
5. Testing Go/No Go LETE								
6. UTDC contract			96,300				96,300	
7. Shop conversion equipment OC Transpo			10,000				10,000	
8. Safety equipment, explosion proofing			7,500		1,000		8,500	
9. Test equipment			5,000		1,000		6,000	
10. Inventory propane parts			7,000				7,000	
11. Miscellaneous engineering & office equipment			2,000		1,000		3,000	
12. Fuelling facility			60,300				60,300	
13. Travel			8,000		3,000		11,000	
14. Publicity			7,000		3,000		10,000	
15. Technical consulting, reports	30,900		16,000		23,100	10,900	70,000	10,900
16. Engineering & technical services (Dereco)			30,000		8,350		38,350	
17. Architectural & drafting (part contract)			35,000		8,500		43,500	
18. Computer program additions			5,050				5,050	
19. Public & driver surveys			14,000		3,000		17,000	
20. Conversion cost, labour (75% MTC, 25% OCT)	14,000		33,520	6,000		9,840	47,520	15,840
21. Conversion cost, expendable materials	4,000		4,000				8,000	
22. Maintenance cost, vehicles increase			22,600		19,000		41,600	
23. Project management and administration		12,300		32,300		13,050		57,650
24. Assigned engineering staff				99,000		42,500		141,500
25. Secretarial services		6,100		10,500		10,500		27,100
26. Staff training, training aids		5,000	10,900	49,100		33,000	10,900	87,100
27. Vehicle inspections, tests		1,000		7,000		3,200		11,200
28. Contingency			38,983	9,900	10,950	4,150	49,933	14,050
TOTAL	312,557	24,400	556,553	213,800	81,900	127,140	975,000	365,340

* Item 1 = 1982/83 = 23,990

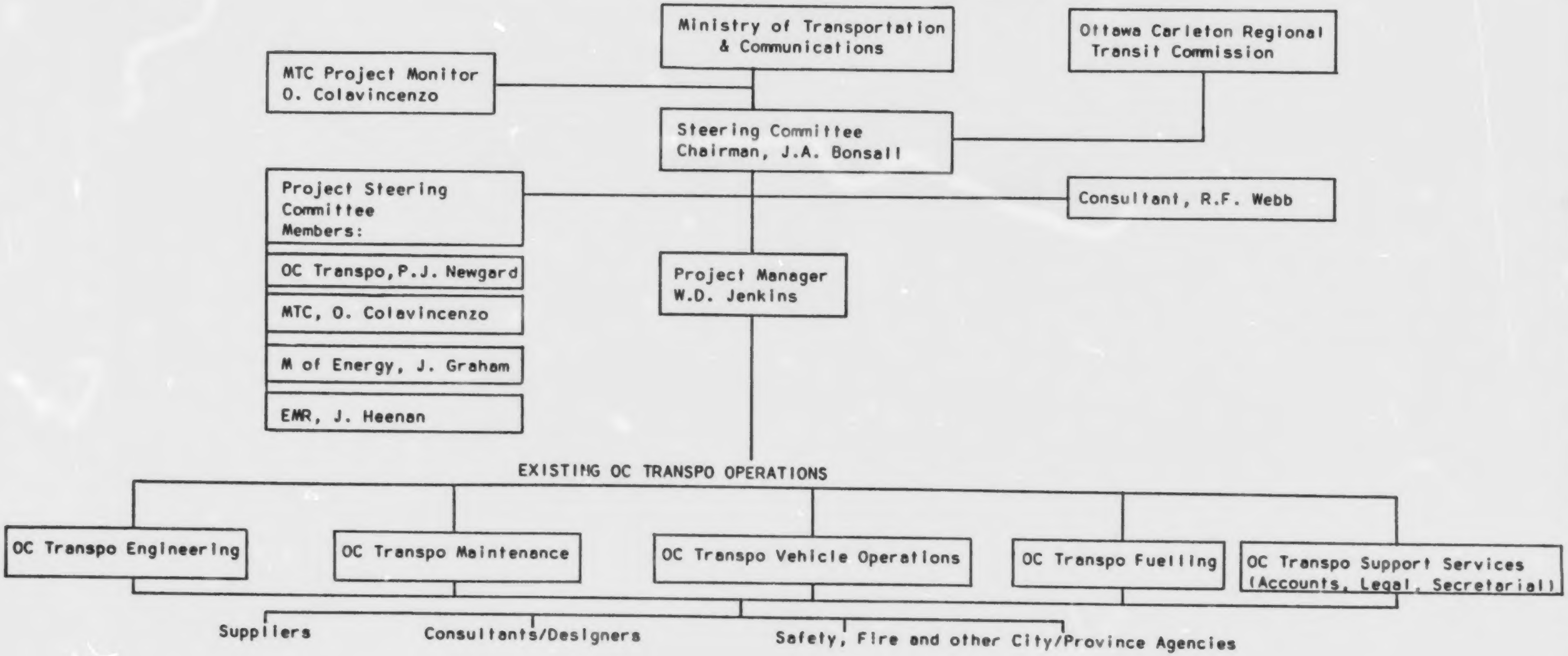
EXHIBIT 2: PROPANE BUS DEMO. SCHEDULE

March 18, 1984

```
                                                  1984              |              1985                 |         1986          |
                                       M  A  M  J  J  A  S  O  N  D |J  F  M  A  M  J  J  A  S  O  N  D |J  F  M  A  M  J  J  A |         NOTES

1.  Test first engine            ------------------xRework fuel system etc.                                                       Noise, vibration, diesel
                                                                                                                                  not tested
2.  GO/NO GO decision                  x                                                                                          Schedule C of contract
3.  Acquire, convert 14 units                      x--------------x   1 unit per week received, converted over 16 weeks           Schedule B.8
4.  Revise vehicle fuel system         x--------x  x--x
                                             D         P
5.  UTDC tests                         x-----------x-----x                                                                        Schedule B. 9
6.  Inspection, acceptance criteria,
    vehicles                              x-----x                                                                                 Schedule F
7.  Fixed fuelling design, analysis       x--------------x  If positive, implement fixed fuelling system by Jan. 1986             Schedule D
8.  Garage revisions                         x----x---------------x  Implement July 1984
9.  Data collection system      x---------------------------------------------------------------------------------------------x
10. Training, safety programs       x--x          x---------------x         x--x            x--x            x--x         x--x
                                        1             4   8  12  15                               15
11. Operations on propane       x-----------------x---x---x---x---x-----------------------------------------------------------x
12. Inspections of engines/               D       P            P             P            P          P            P+D      P
    vehicles                             x--x    x--x        x---x          x--x         x--x       x--x         x--x     x--x    P=Propane:  D=Diesel
13. Passenger & driver surveys                                                        x--x                       x-----x          Schedule E
14. Reports:  Quarterly to
    Steering Committee                 x        x        x        x        x        x        x        x        x        x         Schedule E
    Monthly, Technical                 x  x  x  x  x  x  x  x  x  x  x  x  x  x  x  x  x  x  x  x  x  x  x  x  x  x  x  x         Schedule E
    Special                            x Item 6       x Item 7    x Item 8                                           x Item 13
15. Final Report                                                                                                                  Draft Aug.; Final Nov.
16. Publicity                               ? May 22-26                                                              x            Schedule A.18 1
```

EXHIBIT 3: ORGANIZATION FOR PROPANE DEMONSTRATION


Ministry of Transportation & Communications
Ottawa Carleton Regional Transit Commission
MTC Project Monitor O. Colavincenzo
Steering Committee Chairman, J.A. Bonsall
Project Steering Committee Members:
OC Transpo, P.J. Newgard
MTC, O. Colavincenzo
M of Energy, J. Graham
EMR, J. Heenan
Consultant, R.F. Webb
Project Manager W.D. Jenkins
EXISTING OC TRANSPO OPERATIONS
OC Transpo Engineering
OC Transpo Maintenance
OC Transpo Vehicle Operations
OC Transpo Fuelling
OC Transpo Support Services (Accounts, Legal, Secretarial)
Suppliers
Consultants/Designers
Safety, Fire and other City/Province Agencies

OC TRANSPO PROPANE BUS DEMONSTRATION

QUARTERLY REPORT #2, 1 OCTOBER 1984

1. SUMMARY OF DEMONSTRATION

Delays in the acquisition of engines (due to technical changes and manufacturers' rescheduling) will curtail the demonstration of intermediate numbers of converted buses (at the 2,4,8 level), but not seriously interfere with the demonstration period scheduled for the total 15 bus fleet. The 15 bus fleet demonstration period will be 15 months to 31 March 1986.

Assumption of a major part of the budgeted fuelling station costs by Superior Propane and the rising value of the Canadian dollar compared to the Swiss franc, together with deferred expenditures associated with the delayed demonstration schedule, will result in a carry-forward to 1985/6 and unexpended contingency totalling $156,959 as follows:

	Prior Budget for 1984/5	Revised Budget	Carry-Forward
MTC account	$556,559	438,100	118,459
OCT account	213,800	175,300	38,500
Total	770,359	613,400	156,959

The revised budget assumes no slippage in delivery, conversion and implementation of the demonstration beyond that shown in the revised attached schedule and budget.

The performance of the propane bus and engine while in service has been excellent.

2. ENGINE DEVELOPMENT AND MANUFACTURE

Dereco has built 24 propane engines of the type to be used by OC Transpo, one of which was delivered for the GO/NO GO test. 2 more have been received by OC Transpo (air freighted), 6 were shipped by ocean carrier 5-6 October and the remaining 6 propane engines are to be shipped by ocean freight October 26. The manufacturer, Dereco, reports high reproduceability of engine performance within this production run.

Mr. Jenkins visited Dereco to resolve the outstanding changes needed in engines for the demonstration program. It was decided to set the engine to be delivered to "best fuel economy" consistent with the specified performance. Data are to be provided to OC Transpo on changes that could be made if higher peak power output were required in the future (change in the air-fuel ratio for peak power to 200 HP level would adversely affect the demonstrated fuel economy and the 1.7 to 1 propane to diesel fuel volume ratio established).

Various changes recommended by OC Transpo were incorporated in the engines to be delivered, but it was decided for power output reasons to keep the existing GM muffler and not to relocate the alternator return line, with alternative means sought to reduce engine noise and provide heat shielding.

3. IN-VEHICLE FUEL SYSTEM DESIGN AND MANUFACTURE

A revised in-vehicle fuel storage system was developed by Westeel Ltd. and 15 systems are being manufactured to this design (the first in the first bus will be replaced in January 1985). The new design provides the equivalent of one tank fabricated by manifolding 4 propane vessels. 3 different coatings are being evaluated on 3x5 tanks used in the demonstration. The new design provides: all tank fixtures (the fuel inlet, outlet ports and valves) located on the first vessel and visible from the fuelling door (except the manual shutoff valve which will be relocated for easier access in future purchases). All fixtures are now protected by the shielding. A light display at the driver's dashboard indicates when the tank has reached the recommended minimum fuel charge level of 10%. A means to reduce the hazard of expansion of cold propane by incorporation of a 70% fuel level indicator in addition to the standard 80% level was suggested, but not incorporated in the design. A more radical tank design with automatic shut-off of fuel at selected temperature-dependent fill levels is required to provide maximum winter garaging safety.

4. INTERFACING OF ENGINE/FUEL SYSTEM

Hovey Associates Ltd. of Ottawa were awarded a contract to provide manufacturing and installation drawings for the piping and wiring required to couple the engine in its cradle to fuel system and drive train. The design will be completed on one set of prototype hardware produced by the end of October. 15 sets of the required interconnections will then be fabricated by Hovey Associates.

5. VEHICLE TESTS

The first propane bus was removed from service in September and assigned to Hovey Associates. No records were maintained of its operation in the period, it being decided to begin the record-keeping when the series production engines, tanks and interconnections were available. No adverse reactions to the propane bus were received from the drivers or from the public in the service period to September.

The first propane bus was tested for drive-by noise and vibration. A report on the tests (Technical Report #3) has been prepared and will be issued shortly.

Tests of the Dereco 4-cycle engine in the diesel mode were rescheduled for October by UTDC. UTDC has completed the assembly of the test equipment and is finalizing the acquisition of base line data from tests with the standard GM 2-stroke bus engine (6V71N). The propane engine required for completion of the comparative engine tests at UTDC has now been received.

6. FUEL SUPPLY AND STORAGE

Superior Propane provided the most competitive bid for the supply of propane for the demonstration and, in addition, offered to supply at no added cost 2x2000 gallon storage tanks and a refuelling station, interconnecting pipelines, together with all required safety systems, decals, and training in fuelling and safety matters to the assigned OC Transpo staff. OC Transpo has selected the sites for the bulk storage tanks and the fuelling station and is proceeding with the architectural designs needed, including those for the bulk storage tank foundations and fencing, the trenching to the fuel island, the fuel island itself and the fire proof overhead (propane) heating system for the island, safety systems and communications. Superior is assisting OC Transpo in the process of gaining local and provincial government approval of the fuelling installation. The design will incorporate features to facilitate future expansion, but will not include facilities at the St. Laurent site for fuelling of the non-bus service vehicle fleet of OC Transpo.

7. SAFETY

Two training courses were provided for OC Transpo staff in part fulfilment of the requirements for S6A certification. 29 out of 30 persons instructed and registered passed the S6A certification examination set by Algonquin College.

Three engineers from OC Transpo visited the Vienna Transit Authority to inspect their facilities and safety practices.

A final draft of a safety manual was issued to the Transportation Development Centre of Transport Canada. The report, entitled "A Safety Manual for Propane Bus Systems" was prepared by the R.F. Webb Corporation and OC Transpo under a contract from Transport Canada, and will be available for distribution to other properties by late October 1984.

8. PUBLICITY

The final drafts of the Draft Press Release, Draft Background Information and Draft Brochure have been prepared in conjunction with Synergistics Ltd. A plan has been prepared for papers and demonstrations to be given at the 18 November 1984 annual general meeting of the Canadian Urban Transit Association (CUTA) in Ottawa.

9. BUDGET AND CASH FLOW CHANGES

9.1 Significant Changes in Budget 1984/5

As follows:

Reductions in the Budget are due to the following (MTC and OCT combined):

	BUDGET		
	1984/5	Oct.84	Change
Tanks and lines in vehicle: lower cost design	$79,000	53,000	(26,000)
Fuelling facility: assumption of part cost by Superior Propane	66,300	35,000	(31,300)
Computer Program Additions: included in OC Transpo standard budget	5,050	0	(5,050)
Reduction due to delays in program and engine shipment:			
Shop conversion equipment	10,000	3,000	(7,000)
Dereco technical service	30,000	14,000	(16,000)
Architectural services reduced and delayed	35,000	25,000	(10,000)
Maintenance cost increase	22,600	10,000	(12,600)
Staff training and aids	60,000	47,000	(13,000)
Driver and public surveys	14,000	4,000	(10,000)
Staff reduction in activity management, admin., engineering	141,800	108,300	(33,500)

Additions to the Budget include:

Test equipment: major upgrade in specifications	5,000	40,000	+35,000
Publicity: increase in contract value	7,000	10,000	+ 3,000

The 1984/5 Budget forecast is now:

MTC Expense	556,559	438,100	118,459
OC Transpo	213,800	175,300	38,500
TOTAL	770,359	613,400	156,959

9.2 Budget Items for Consideration/Discussion

1.	Extend demonstration period beyond 31 March 1986,	
	OC Transpo added expense being met by payment for	
	budgeted OC Transpo staff expenses in 1984/5:	$118,300
	(Admin. and management	28,300
	assigned engineering	80,000
	secretarial and services	10,000)
2.	Purchase 2 propane engines in lieu of spares only:	38,600
3.	Additional purchase of 2 GM or other N. American propane engines, estimated	85,000
4.	Develop engineering costs and preliminary design for improved fuel control at fuelling station (for cold fill safety) estimated	30,000
5.	Purchase dual fill tank system (fill L- and R-hand side of bus), estimated	4,750
6.	Prepare manual "Fighting Propane Fires" estimated	33,500
7.	Continue contingency item for reconversion to diesel fuel	67,500

10. REPORTS ISSUED

10.1 Technical Reports

To date the following reports have been prepared:

1. 19.2.84 "Report on Test of OC Transpo LPG-Engined City Bus".
2. 21.3.84 "Report on Fuel Economy Tests of OC Transpo LPG-Engined City Bus".
3. To be issued in October 1984. "Noise and Vibration Testing of OC Transpo LPG-Engined City Bus".
4. 29.9.84 "Notes on Reconversion of Propane Buses to Diesel Operation" and "Notes on Propane Engine Developments".

Technical Letter

23.4.84 To W.D. Jenkins from R.F. Webb. Propane price, diesel price forecast.

Other Reports

29.9.84 Publicity drafts: "Draft Press Release", "Draft Background Information: Propane in Transit", "Draft Brochure: Propane in Transit".

PROPANE BUS DEMO. SCHEDULE

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                                                            1984             |               1985                |          1986         |
                                        M  A  M  J  J  A  S  O  N  D |J  F  M  A  M  J  J  A  S  O  N  D |J  F  M  A  M  J  J  A |          NOTES
                                                ___________________________________________________________________________________________________________________
                                                             x----------x
 1. Test first engine                           x-----------xRework fuel system                                           :

 2. GO/NO GO decision                           x                                                                         :
 3. Acquire, convert 14 units                                        x------x                                             :
 4. Revise vehicle fuel system                  x--------x x--x                                                           :
                                                                D       P                                                 :
 5. UTDC tests                                             x-------x x-----x                                              :
 6. Inspection, acceptance criteria,                                                                                      :
    vehicles                                      x-----x                                                                 :
 7. Fixed fuelling design, analysis                        x------x                                                       :
 8. Garage revisions                                       x---------------x                                              :                For demo. only
                                                                                                                                ?
 9. Data collection system              x---------------------------------------------------------------------------------------------x |             ?
                                                                                                                                   ?
10. Training, safety programs               x--x          x---------------x         x--x            x--x            x--x  :      x--x   |  Budget discussion 11.10.4
                                                1                   2   8                                  15                   ?
11. Operations on propane               x------------------------x x-x x-x x----------------------------------------------------------x |- determines termination of
12. Inspections of engines/                       D       P            P             P            P          P           P+D      P ?   |  demo.
    vehicles                                     x--x    x--x        x---x          x--x         x--x       x--x         x--x     x--x  |  P=Propane:  D=Diesel
13. Passenger & driver surveys                                       x---x                    x--x                       x-----x        |
14. Reports:  Quarterly to
    Steering Committee                         x                 x        x        x        x        x        x        x  :     x
            Technical                           x                   x                                                     :
                                               1,2                 3,4                                                    :
15. Final Report                                                                                                          :         x  Draft Aug.; Final Nov.
16. Publicity                                        Documents        CUTA
                                                    x----------x      x---x                                                 x-------x
                                                                    Ministry?
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REVISED FORECAST

Revision #1 October 1, 1984

CASH FLOW PROPANE DEMONSTRATION OC TRANSPO (DOLLARS)

	FY 1983/4 and prior			FY 1984/5 - MTC					FY 1984/5 OCT					
	MTC	OCT	TOTAL	1Q	2Q	3Q	4Q	TOTAL	1Q	2Q	3Q	4Q	TOTAL	TOTAL 1984/5
1. One time engine development contract	64,033		64,033											
2. P.O. propane engines Dereco	202,882		202,882			64,400		64,400						64,400
3. P.O. diesel engine Dereco	17,732		17,732											
4. Other conversion equipment, tanks, lines	3,000		3,000			35,000	18,000	53,000						53,000
5. Testing Go/No Go LETE														
6. UTDC contract					43,950	27,000	25,350	96,300						96,300
7. Shop conversion equipment OC Transpo						2,000	1,000	3,000						3,000
8. Safety equipment, explosion proofing						3,000	1,500	4,500						4,500
9. Test equipment						5,000	35,000	40,000						40,000
10. Inventory propane parts						5,000	2,000	7,000						7,000
11. Misc. engineering & office equipment						1,000	6,400	7,400						7,400
12. Fuelling facility							35,000	35,000						35,000
13. Travel						6,500	1,500	8,000						8,000
14. Publicity					5,000		5,000	10,000						10,000
15. Technical consulting, reports	30,900		30,900	4,000	4,000	4,000	4,000	16,000						16,000
16. Engineering & technical services (Dereco)						11,000	3,000	14,000						14,000
17. Architectural & drafting (part contract)						5,000	20,000	25,000						25,000
18. Computer program additions								N/C						N/C
19. Public & driver surveys							4,000	4,000						4,000
20. Conversion cost, labour (75% MTC, 25% OCT)	14,000		14,000			13,000	20,500	33,500			2,000	4,000	6,000	39,500
21. Conversion cost, expendable materials	4,000		4,000			4,000		4,000						4,000
22. Maintenance cost, vehicles increase				600		4,400	5,000	10,000						10,000
23. Project management & administration		12,300	12,300						1,800	4,500	9,000	13,000	28,300	28,300
24. Assigned engineering staff									11,000	21,000	24,000	24,000	80,000	80,000
25. Secretarial services		6,100	6,100						1,600	2,400	2,900	3,100	10,000	10,000
26. Staff training, training aids		5,000	5,000		1,500		1,500	3,000	2,500	8,000	15,000	18,500	44,000	47,000
27. Vehicle inspections, tests		1,000	1,000						700	1,000	2,650	2,650	7,000	7,000
TOTAL NEW BUDGET	336,547	24,400	360,947	4,600	54,450	190,300	188,750	438,100	17,600	36,900	55,550	62,250	175,300	613,400
BUDGETED 30 APRIL 1984	336,547	24,400	360,947	39,546	92,880	291,350	132,783	556,559	23,100	51,900	67,050	71,750	213,800	770,359
Contingency and/or carry forward								118,459 MTC					38,500 OCT	156,959 TOTAL
				AMJ	JyAS	OND	JFM							

OC TRANSPO PROPANE BUS DEMONSTRATION

QUARTERLY REPORT #3 1 JANUARY 1985

1. SUMMARY OF DEMONSTRATION

The "Propane in Transit" demonstration program was officially launched on 21 November 1984 with a press conference and a ceremony involving the Chairman of the Commission and representatives of the supporting Ontario and federal government ministries. Further details of the demonstration were presented at the CUTA meeting on the same date.

All propane engines and tanks (including certain spares) required for the 15 bus demonstration have been received and bus conversions are being made as vehicles can be spared from service. Two propane buses were in operation at 1 January 1985 and the design of the engine interfacing to the bus and in-vehicle fuel system is complete. The bulk fuelling facility is being installed to designs produced by OC Transpo and Superior Propane with completion of the installation scheduled for February 28.

Activity in the quarter to March 31 will emphasize garage conversions for the safe storage, maintenance and repair of buses, completion of conversions, and the initiation of the data collation from the 15 propane and one 4-cycle diesel-engined fleet.

Expenditures to 31 December 1984 invoiced to MTC total $548,249.88, with $395,690.12 of the approved MTC budget as yet unexpended. Further expenditures totalling $257,750 will be invoiced to MTC in the period to 31 March 1985 when the total invoiced will be $806,000 (82.7% of the MTC budget of $975,000). A summary of the actual and projected budget and expenditures is as follows:

	ACTUAL		PROJECTED			
		Invoiced (MTC)/Expended (OCT)			Unexpended at 31.3.85	
	Total Budgeted	To 1.1.85	1.1 to 31.3.85	Total	$'s	% Budget
To MTC Acct	$975,000	548,250	257,750	806,000	169,000	17.3
To OCT Acct	365,340	110,050	30,000	140,050	225,290	61.6
TOTAL	$1,340,340	658,300	287,750	946,050	394,290	29.4%

Details of the invoices submitted to MTC to 1.1.85 are given in Exhibit 1.

The schedule of activities compared to accomplishments at 31 December 1985 is given in Exhibit 2. The projected cash flow now forseen for the project is given in Exhibit 3. (This may be revised to meet the new requirements of the extended demonstration and of the change from CREDA to ENERDEMO support from the federal government).

2. DISCUSSION OF BUDGET AND EXPENDITURE DECISIONS IN PERIOD

The budget options discussed at the October 11 Steering Committee meeting have been implemented as follows:

2.1 Long Term Effect

Extension of the demonstration period beyond 31 March 1985 will be considered in 1985. Expenditures to date indicate an extension to 31 December 1986 can be financed within the overall budget while still completing the MTC budget commitment by 31 March 1986.

2.2 Shorter Term Expenditures (to 31 March 1985)

2.2.1 Spares

A spare propane engine has been delivered. A spare and new style fuel tank will be ordered.

2.2.2 Conversion components

The 16 alternators ($48,000) and other components ($13,000) to complete bus conversions were ordered.

2.2.3 Test equipment

A test facility to assist engine set-up, ignition timing, fuel economy and exhaust, and optimization for emissions was ordered at a cost of $17,000.

2.2.4 Bulk fuel storage

Although Superior Propane has leased the fuel storage tanks and supplied other fuelling facilities at no charge for the period of the demonstration, OC Transpo's decision on the location of the propane meter involved added underground piping and a non-recoverable added investment of $24,000 by OC Transpo.

2.2.5 Technical consulting

$4,000 budgeted in the period.

These items account for $106,000 of the $257,750 to be charged to the MTC account in the period to 31.3.85.

2.3 Other Commitments to 31.3.85

Expenditures will be committed in the period to 31.3.85 to initiate the following:

1. Installation of explosion proofing and gas detection instrumentation and other changes in the St. Laurent garage (total sub budget estimated at $60,000 is proposed for this activity).
2. Production of a short form safety booklet ($5000).
3. Engine optimization for cold start and cold running ($21,000 total).
4. Investigation of an improved fuelling and metering system and dual-position filling tank designs ($6,000).
5. Development of a computer-based information retrieval and analysis program (technical and economic data) ($25,750).
6. Continued program personnel support ($34,000).

Expenditures to be invoiced to MTC in these categories to 31.3.85 are estimated at $151,750, bringing the total MTC invoiced expenditures to 31.3.85 to $806,000 (82.7% of the total MTC program budget of $975,000).

3. ENGINE SUPPLY AND TEST CONTRACTS

The 14 propane engines and one diesel have now been received, completing the delivery of 15 (including the first engine for the GO/NO GO test) propane engines and the 4-cycle diesel set specified in the demonstration contract. A saving of about $10,250 was achieved due to currency changes since the order was placed.

A further order for one propane engine was placed with Dereco to provide an occasional source of spares and a back-up engine during the demonstration. This item is shown as #28 on Exhibit 1 ($16,529 "contingency").

The completed one-time engine development contract and the engineering and technical services contract with Dereco contain a balance of about $41,000. Engine performance to date indicates that technical services may not be required from Dereco at the budgeted level. A problem of cold starting of the propane engine is anticipated and a Dereco offer to optimize the engine for cold starting is under consideration. The cost of this work would be $21,000; it could be completed within 10 weeks of contract award and funded within the present program.

Dereco has proposed a further program to optimize the fuel consumption, power output and exhaust gas emissions for Dereco propane engines operated on 3 qualities of propane. This would require 25 weeks of work and a budget of $90-93,000. This work is similar to that previously planned for UTDC. Funds for it are not included in the propane demonstration budget.

The test of the Dereco propane engine has been initiated at UTDC after delays and problems with the equipment were solved in the base line testing of the GM 2-stroke 6V-71 engine. Completion of the contract is anticipated by 31 March 1985.

Substantial upgrading of the UTDC test facility and commitment of senior staff at UTDC to engine testing programs will be necessary if UTDC is to undertake more complex work than that involved in the present contract.

4. IN-VEHICLE FUEL TANKS

The systems required for the demonstration have been delivered and now incorporate the safety mesh and various coatings required for evaluation.

Investigation has begun of two systems to improve the safety, speed and accuracy of propane fuelling: one involving the development of an automated fuel weighing and flow control system primarily to prevent fuel tank overfilling; and a fuel tank design to permit filling from either or both sides of the propane bus.

Fuel tank spares will be ordered when a decision is made on the effectiveness of the dual filling design.

5. INTERFACING COMPONENTS AND DESIGN

Hovey Associates have successfully completed the design and prototype production of the cradle and engine/fuel tank interfacing. The first bus conversion using the Hovey prototype was completed and production of a further 15 sets of piping and other interfacing were underway at the 1 January 1985 reporting date.

6. CONVERSIONS AND SCHEDULE

Familiarization with the new engine, ignition system and other non-standard items continues and the learning process has resulted in slower than projected conversions. At 1 January 1985 only two buses had been converted and the schedule for completion of conversions has been changed to mid-March.

Problems encountered in the period included engine backfiring due to ignition timing errors, engine oil leaks and overheating of the alternator due to non-grounding. Other details of the conversions and bus performance are reported in the minutes of the January 24 Steering Committee meeting.

7. BUS OPERATION IN PERIOD

No problems were encountered in operations, but the first propane bus (#7930) was removed from service for use by Hovey Associates in the design of the interfacing system. Bus #7926 with the Hovey-designed prototype connections was operated in service in the period.

8. FUEL STORAGE AND FUELLING FACILITY

The contract for propane fuel supply by Superior Propane was signed. As part of the agreement Superior has installed the fuel pump and fuel tanks at no cost, but a decision was made to locate the propane meter distant from the garage and the cost of the required pipeline extension ($24,000) was charged to the MTC account.

Completion of the fuelling facility installation and final safety inspection is scheduled for the end of February 1985.

Safety considerations arising from the potential for overfilling of the in-vehicle fuel tanks and the potential for propane leaks due to propane expansion as vehicles are moved from the cold outdoor fuelling facility to indoor garaging are part of the consideration being given to the design of a new fuel filling-metering system.

9. FUEL QUALITY AND RELATIVE COST

Arrangements have been made with Superior Propane to provide analysis of the HD-5 grade propane supplied under the contract. The HD-5 specification is broad and attention is being given to the potential fuel economy and cost savings that could be gained through purchase of low propylene content propane (i.e. gas-derived product).

The price of diesel fuel to OC Transpo was increased in the quarter to 41.6¢/litre (from 39.4¢ in the previous period).

At the propane efficiency level demonstrated in the test the present contract price for propane is equivalent to a diesel price of 30.4¢/litre.

10. TRAINING

Arrangements have been made with Algonquin College for the OC Transpo staff who now hold the S6A certificate to take a further course leading to S6B certification which will allow OC Transpo to comply with the new self-certification requirements for propane vehicle conversions.

Preliminary discussions were held with the Ottawa Fire Department concerning fire training.

11. PUBLICITY

The program for official launch of the propane demonstration program on 21 November 1984 is attached (Exhibit 4). Copies of the publicity and briefing documents prepared for the press by OC Transpo in conjunction with Synergistics Ltd. under the title "Propane in Transit" were released 21 November 1984. Copies of the papers are available from Mr. W. Jenkins of OC Transpo. Copies of the Ottawa press articles are given in Exhibit 5.

A series of three papers on the propane demonstration program were delivered to the Canadian Urban Transit Association on the occasion of their Annual General Meeting in Ottawa on 21 November 1984. The papers were:

"Organization of the OC Transpo Propane Demonstration" by Mr.P. Newgard.
"The Rationale for the Propane Bus Demonstration" by Dr. R.F. Webb.
"A Report on the Status of the Demonstration" by Mr. W. Jenkins.

Copies of the papers are to be issued as Technical Report #5 on or before 15 February 1985.

12. REPORTS ISSUED TO DATE AND IN PREPARATION

Technical Reports

1. Report on OC Transpo LPG-Engined City Bus. Issued 19.2.84.
2. Report on Fuel Economy Tests of OC Transpo LPG-Engined City Bus. Issued 21.3.84.
3. Noise and Vibration Testing of OC Transpo LPG-Engined City Bus. To be issued after new tests scheduled for April 1985.
4. Notes on Reconversion of Propane Buses to Diesel Operations, and Notes on Propane Engine Development. Issued 29.9.84.
5. Papers presented at CUTA Meeting, Ottawa, 21 November 1984. To be issued before 15 February 1985.
6. Detailed Data Acquisition Program for Propane Bus Demonstration. In preparation for issue on or before 15 February 1985.

Technical Letter

Propane Price, Diesel Price Forecast. R.F. Webb to W. Jenkins issued 23.4.84.

Quarterly Reports

#1 Issued 12 March 1984
#2 Issued 1 October 1984
#3 Dated 1 January, issued 24 January 1984.

Minutes of Steering Committee Meetings (all at OC Transpo, Ottawa)

#1 27 March 1984
#2 30 April 1984
#3 5 July 1984
#4 11 October 1984
#5 In preparation after meeting 24 January 1985.

Publicity

Various press releases entitled "Propane in Transit", released 21 November 1984.

Exhibit 1 (3rd Quarterly Report)

OC TRANSPO PROPANE BUS DEMONSTRATION - ITEMS BUDGETED MTC

	Budget	Invoice 8877	Invoice 9655	Invoice 7881	Invoice 8427	Invoice 10005	Spent to Date	Balance in Hand	
1. One time engine development contract	72,720	23,990.00	40,042.50				64,032.50	8,687.50	Complete
2. P.O. propane engines Dereco	276,000		17,732.00	185,150.00		63,550.08	266,432.08	9,567.92	Complete
3. P.O. diesel engine Dereco	18,400		17,732.00				17,732.00	668.00	Complete
4. Other conversion equipment, tanks	82,000			3,000.00		37,561.85	40,561.85	41,438.15	
5. Testing Go/No Go LETE	10,000						-	10,000.00	
6. UTDC contract	98,000					46,256.35	46,256.35	51,743.65	
7. Shop conversion equipment OC Transpo	10,000					5,391.00	5,391.00	4,609.00	
8. Safety equipment, explosion proofing	8,500						-	8,500.00	
9. Test equipment	6,000				575.00		575.00	5,425.00	
10. Inventory propane parts	7,000					1,369.17	1,369.17	5,630.83	
11. Misc. engineering & office equipment	3,000						-	3,000.00	
12. Fuelling facility	60,300						-	60,300.00	
13. Travel	11,000				67.56	10,670.46	10,738.02	261.98	
14. Publicity	10,000				4,464.15	8,151.17	12,615.32		Complete
15. Technical consulting, reports	70,000			30,900.00	4,000.00	4,000.00	38,900.00	31,100.00	
16. Engineering & technical services (Dereco)	38,350					6,046.49	6,046.49	32,303.51	
17. Architectural & drafting (part contract)	43,500						-	43,500.00	
18. Computer program additions	5,050						-	5,050.00	
19. Public & driver surveys	17,000						-	17,000.00	
20. Conversion cost, labour (75% MTC, 25% OCT)	47,520			14,000.00			14,000.00	33,520.00	
21. Conversion cost, expendable materials	8,000			4,000.00	753.32		4,753.32	3,246.68	
22. Maintenance cost, vehicles increase	41,600					2,317.58	2,317.58	39,282.42	
28. Contingency	0					16,529.20	16,529.20	-	
	943,940	23,990.00	75,506.50	237,050.00	9,860.03	201,843.35	548,249.88	395,690.12	

Figures as at 1.1.85

Exhibit 2 (3rd Quarterly Report)

PROPANE BUS DEMO. SCHEDULE

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                                                    1984             |                1985               |           1986        |
                                        M  A  M  J  J  A  S  O  N  D |J  F  M  A  M  J  J  A  S  O  N  D |J  F  M  A  M  J  J  A |            NOTES
                                                     x----------x
1.  Test first engine                   x-----------xRework fuel system    COMPLETE

2.  GO/NO GO decision                   x     COMPLETE                                                             REVISION IN 1986 TO DEMO. TERMINATION DATE
3.  Acquire, convert 14 units                                x------x-------# CONVERSIONS BEHIND SCHEDULE            AND ISSUE OF FINAL REPORTS
4.  Revise vehicle fuel system          x--------x  x--x   COMPLETED DESIGN
                                                        D       P
5.  UTDC tests                                      x-------x x----x--------# BEHIND SCHEDULE AT UTDC
6.  Inspection, acceptance criteria,
    vehicles                               x-----x         COMPLETED
7.  Fixed fuelling design, analysis                x------x-----------------# REVISED: BULK FUEL SYSTEM BEING INSTALLED             For demo. only
8.  Garage revisions                               x---------------x--------# REVISED SAFETY SYSTEMS
9.  Data collection system      x-------------------------------------------# MAJOR DESIGN-------------------------------------x
                                                                                                                           ?
10. Training, safety programs       x--x           x----------------x        x--x             x--x            x--x         x--x
                                        1                        2                                  15
11. Operations on propane       x------------------------x x-x x-x x--------#8x------------------------------------------------x
12. Inspections of engines/               D       P            P              P            P          P             P+D       P ?
    vehicles                             x--x    x--x        x---x          x--x         x--x        x--x          x--x      x--x        P=Propane:  D=Diesel
13. Passenger & driver surveys                               x---x                    x--x                        x-----x
14. Reports:  Quarterly to                                          ON SCHEDULE
    Steering Committee                  x                x       (x)       x        x         x        x        x        x
             Technical                   x                  x
                                        1.2               (3)4  #3 NOT ISSUED 1.1.85, #5 IN PREPARATION
15. Final Report                                                                                                             x  Draft Aug.; Final Nov.
16. Publicity                                Documents        CUTA"   COMPLETE CUTA PAPERS ISSUED AS TECHNICAL
                                            x---------x       x---x   REPORT #5                                       x------x
                                                             Ministry
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Exhibit 3 (3rd Quarterly Report)

CASH FLOW GUIDE (FOR PLANNING PURPOSES)

Assumes MTC contributions to 31.3.86
OCT contributions to 31.12.86

	OC TRANSPO		MTC	
	Quarter	Annual	Quarter	Annual (Govt. year end)
1983		$24,400		$312,557
1984-1.1.85	3 Quarters $85,650		3 Quarters to 1.1.85 $235,693 *	
1985				
Jan.-Mar.	$30,000	115,650	$257,750	493,445
Apr.-June	12,000		40,000	
Jul.-Sept.	10,000		40,000	
Oct.-Dec.	8,000		40,000	
1986				
Jan.-Mar.	8,000	38,000	49,000	169,000
Apr.-June	60,000		0	975,000 PROGRAM TOTAL MTC
Jul.-Sept.	60,000		0	
Oct.-Dec.	67,290		0	
		187,290		
PROGRAM TOTAL OC TRANSPO		365,340		
GRAND TOTAL MTC & OCT		$1,340,340		

* Includes $23,990 for committed propane pipe/trench fuel facility

Note (added Feb. 1, 1985):

Revised program to accommodate ENERDEMO requirements may extend the test period and increase the total budget (by up to $80,000)

Exhibit 4

"Propane in Transit"

Launch Event - Wednesday, November 21

10:00 Meet in York Room, Convention Level, Skyline Hotel, corner of Queen and Lyon Streets, Ottawa.

10:13 Move to Frontenac Room.

10:15 Mr. Al Cormier, Executive Director of the Canadian Urban Transit Association: Welcome and Introduction of Mr. Andrew Haydon, Chairman of the Regional Municipality of Ottawa-Carleton and Chairman of the Ottawa-Carleton Regional Transit Commission.

10:17 Mr. Andrew Haydon: Remarks;
Introduction of Mr. John McDermid, M.P. for Brampton-Georgetown and Parliamentary Secretary to the Honourable Pat Carney, M.P., Minister of Energy, Mines and Resources, Government of Canada.

10:20 Mr. McDermid: Remarks.

10:23 Mr. Haydon introduces Mr. Roger Higgin, Assistant Deputy Minister, Programs and Technologies, Ministry of Energy, Government of Ontario.

10:24 Mr. Higgin: Remarks.

10:27 Mr. Haydon introduces Mr. Morley Kells, M.P.P. for Humber, Parliamentary Assistant to the Honourable John Snow, Minister of Transportation and Communication, Government of Ontario.

10:28 Mr. Kells: Remarks.

10:31 Mr. Cormier invites media representatives, representatives of sponsoring agencies and interested delegates to participate in ribbon-cutting ceremony at Queen Street entrance, Lower Lobby level (to the right out of elevators, through double doors, immediately to the left).

10:36 Mr. Haydon, Mr. McDermid, Mr. Higgin and Mr. Kells each given a pair of scissors to cut beside appropriate bow on ribbon across doors of bus.

Mr. Haydon - Candy Striped
Mr. McDermid - Red
Mr. Higgin - Ontario Blue
Mr. Kells - Ontario Blue

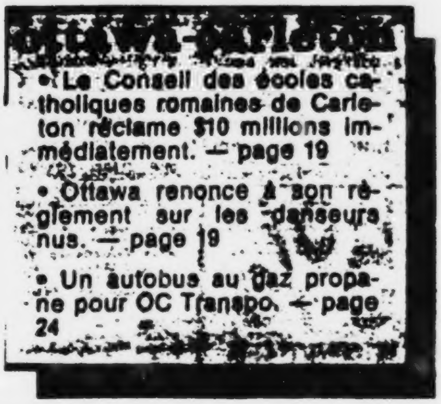
10:37 All who wish board the bus for a short ride.

10:42 Return to hotel.

10:45 Technical session begins.

Exhibit 5

Press Releases



ottawa-carleton

- Le Conseil des écoles catholiques romaines de Carleton réclame $10 millions immédiatement. — page 19
- Ottawa renonce à son règlement sur les danseurs nus. — page 19
- Un autobus au gaz propane pour OC Transpo. — page 24

LE DROIT, Ottawa, 22 Nov. 1984

SPECIAL
930
OC Transpo

Au propane

De l'extérieur, ce véhicule d'OC Transpo ressemble à s'y méprendre à tous les autres présentement en service. Il a pourtant pour caractéristique d'être mu au gaz propane, un sous-produit du traitement du gaz naturel, une ressource très abondante et peu dispendieuse au Canada. Si l'expérience d'OC Transpo dans l'utilisation du gaz propane s'avère concluante, il pourrait en résulter des économies de plus de $1 million, au seul chapitre des coûts énergétiques, pour le transporteur régional. Lire en page 24.

(Photo LE DROIT par Alain Legault)

LE DROIT, Ottawa, 22 Nov. 1984, p. 19

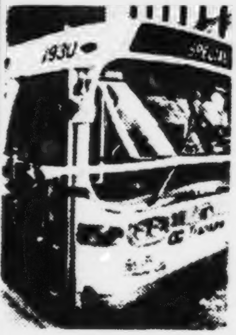
Exhibit 5 (cont)

24— LE DROIT, OTTAWA, JEUDI 22 NOVEMBRE 1984

Des économies de $1 million par an

par Mario Lemoine

OTTAWA — Si l'expérience d'OC Transpo dans l'utilisation du gaz propane comme substitut au diesel pour mouvoir ses autobus s'avère concluante, il pourrait en résulter une économie de plus de $1 million par année pour l'organisme, au seul chapitre des coûts énergétiques.



C'est la déclaration qu'a faite M. John Bonsall, directeur général d'OC Transpo, lors de la mise en service commerciale, hier, du premier autobus mu au propane au Canada, dans un réseau de transport en commun.

D'ici la fin de l'année, quinze autobus seront convertis au propane pour les fins de cette expérience. M. Bonsall pense qu'il faudra au moins deux ans d'utilisation régulière de ces autobus pour savoir si les économie escomptées se réaliseront, compte tenu des conditions climatiques et routières propres au Canada.

C'est précisément ce que l'on veut mesurer puisqu'un certain nombre d'autres entreprises de transport en commun en d'autres pays ont, depuis quelques années, utilisé avec succès le propane pour faire fonctionner leurs autobus. La mise à l'essai la plus remarquable à cet effet s'est effectuée à Vienne, en Autriche, où un parc de 400 autobus fonctionnent de la sorte.

Au Canada, le gaz propane est une ressource à la fois abondante et peu dispendieuse. Actuellement, seulement la moitié de ce sous-produit du traitement du gaz naturel est utilisée au pays; le reste est exporté, principalement aux Etats-Unis.

De plus, son prix, en Ontario est actuellement d'environ 50% du prix de l'essence et du diesel.

Comme carburant de transport, le propane offre aussi un certain nombre d'autres avantages, notamment au niveau de l'entretien des véhicules et du respect de l'environnement.

Ainsi, lorsqu'il est entreposé sous forme liquide, le propane pénètre, entièrement vaporisé, dans les cylindres du moteur, ce qui permet de réaliser une meilleure accélération et d'assurer un fonctionnement plus efficace par temps froid.

Il se consume sans résidu, ce qui évite l'encrassement des bougies et prolonge la lubrification des pièces. De ce fait, on peut s'attendre à ce que le moteur dure plus longtemps.

Toujours au niveau du respect de l'environnement, il est à noter que le propane produit des émissions d'échappement très faibles, surtout en ce qui touche aux particules de monoxide de carbone. Cependant, on relève des niveaux d'oxyde d'azote semblables aux moteurs diesels conventionnels.

Exhibit 5 (cont)

The Citizen, Ottawa, Thursday, November 22, 1984, Page C15

Transpo to test propane-fueled bus engines

By Doug Kelly
Citizen staff writer

OC Transpo will be the first Canadian transit system to convert some of its buses to propane.

Under a three-year trial announced Wednesday, the diesel engines in 15 Transpo buses will be replaced with propane engines from Italy at a cost of $1.3 million.

With the provincial and federal governments contributing $487,500 each, Transpo will pick up the remaining $365,340.

Although thousands of smaller vehicles across Canada are running on the gaseous fuel, it's never been used to power buses. This project will determine cost and performance, as well as maintenance requirements of propane engines.

Transit authorities are concerned about the rising cost of petroleum-based fuel because of shortages in supply and increasing government taxes.

Propane is produced from natural gas and Canada currently produces twice the propane it uses.

Other advantages are that propane burns cleaner and the engines run much more quietly than those on petroleum-based fuels.

It is hoped the propane engines will be easier to start on cold winter mornings — a problem that has long been associated with diesel engines.

If it proves successful, the fuel savings on each bus could amount to between $2,000 and $3,000 a year, based on current propane and diesel prices. Propane costs about 22 cents a litre, — about half of price of diesel fuel.

LE DROIT
OTTAWA, MARDI —23
20 NOVEMBRE 1984

Un autobus au propane

OTTAWA — OC Transpo profitera, demain, du congrès de l'Association canadienne du transport urbain, en cours à Ottawa, pour lancer dans les rues le premier des quinze autobus modifiés au propane qui assureront la cueillette des passagers: une première, dit-on, au Canada.

La cérémonie se déroulera à 10h15 du matin, devant l'hôtel Skyline, lieu du congrès.

Selon Mme Cynthia Taylor, vice-présidente du groupe de consultants Synergetics Ltd, l'autobus GM ressemblera à tous ceux qui parcourent les rues. Mais on est allé chercher, pour le rééquiper, un moteur au propane conçu en Italie et en France et fabriqué en Suisse par la firme Iveco. On ne pouvait trouver en Amérique du Nord la technologie appropriée.

On ne pouvait, hier, donner de chiffres sur la consommation possible du nouveau véhicule. Elle est moindre que pour les autobus «ordinaires» toutefois.

«Autrement, l'expérience n'en serait pas une», a déclaré Mme Taylor.

Mais, dès maintenant, elle rassure ceux que la crainte retiendrait de prendre le nouvel autobus parce qu'il fonctionne au gaz propane plutôt qu'au mazout. Il est parfaitement sécuritaire, déclare-t-elle.

OC Transpo compterait, d'ici un mois, mettre en service quatorze autres autobus modifiés et elle a déjà un certain nombre de camions légers et de véhicules utilitaires fonctionnant au propane. Mais c'est la première expérience avec les passagers.

L'expérience est menée conjointement pour trois ans et défrayée par OC Transpo, le ministère fédéral de l'Energie, des mines et des Ressources, et les ministères ontariens de l'Energie comme des Transports et Communications.

APPENDIX B

TECHNICAL REPORTS

TECHNICAL REPORT #1

19.2.84

PROPANE BUS DEMONSTRATION

REPORT ON TEST OF THE OC TRANSPO LPG-ENGINED CITY BUS

CONTENTS

1. DYNO-TESTING OF GM BUS OC TRANSPO WITH IVECO LPG ENGINE

1.1 Engine cooling system
1.2 Engine performance
    1.2.1 Performance results
    1.2.2 Minimum requirements
    1.2.3 "History" of Bus 7930
    1.2.4 Statistics on the engine performance of GM Buses at OC Transpo
    1.2.5 Summary

2. ROAD PERFORMANCE TESTING IN DIFFERENT CITY SERVICES

2.1 Basic data of diesel and LPG bus
2.2 Testing conditions
2.3 Test results regarding engine performance

3. SUMMARY/CONCLUSIONS

1. DYNO-TESTING OF GM BUS OC TRANSPO WITH IVECO LPG ENGINE

1.1 Engine cooling system

- Because of the unacceptable results of the dyno-testing at OC Transpo in December with the standard 6-blade Iveco fan, the cooling system was improved.
  - Dereco supplied a switch-off clutch for the fan
  - OC Transpo adapted a bigger 8-blade fan (used in the Flyer bus)

- Under full load conditions the switch-on temperature of the fan is about 197°F, the switch-off point at about 185°F.

- The engine cooling system was tested on the dyno of OC Transpo at a constant speed of 41 mph (equal to about 1500 engine rpm) under constant full load conditions (82 hp with fan on)
  - with an ambient temperature of 96-102°F (air intake of radiator achieved with the unventilated test room and air intake from the top of the bus) the water temperature after the engine reached a steady value of 196°F (fan on)
  - with an ambient temperature of 85-95°F (ventilated test room) the water temperature after engine reached a steady value of 194°F (fan on).

- For these tests the system overpressure (controlled at the expansion tank) was 4 psi.
  Iveco's installation instructions recommend a 6 psi overpressure.
  A higher overpressure increases the water flow under high temperature conditions.

- Conclusion: The present cooling system is sufficient but can be improved by adopting the 6 psi increased overpressure and by improved shrouding of the fan housing.

1.2 Engine performance

Dyno-TESTING OF THE LPG-powered bus and a road comparison with one high-performance GM diesel bus (with an unusually high measured dyno-power of 110 hp) indicated the need to evaluate the LPG bus against the average of a number of buses in service at OC Transpo.

1.2.1 Achieved engine performance (February '84)

With an ignition timing of -3° at 600 rpm, 12° at 2100 rpm and under stable engine temperature conditions the power output at 41 mph corresponding to 1500 rpm is: with fan off: 93-95 hp
with fan on: 83-85 hp
(engine air intake temperature of about 85°F)
(Note that the propane engine requires heat input to the vapourizer and tests should therefore be conducted on the warmed-up engine).

1.2.2 Minimum requirements

According to the contract, Dereco has to achieve the same performance as the Detroit Diesel engine Model 6V-71N with C55 injectors as it is shown on the performance curve E4-7061-51-6 (at SAE standard ambient conditions).
The required engine power at 1500-1550 rpm is therefore 139-143hp.
According to OC Transpo, the LPG bus should perform on the road equal to an average diesel bus.
The minimum acceptable power for diesel buses at OC Transpo is currently 80 hp with fan off at 41 mph corresponding to an engine speed of 1500-1550 rpm. If the measured power is below 80 hp, an engine overhaul is necessary. (Consideration is being given by OC Transpo to increase the reject level to 85 hp).
The sum of measured power and parasitic power (position drive)

will give an indication of the engine power at this point.
It results in an engine power of
85 hp (with fan on) + min 60 hp parasite = 145 hp total.

1.2.3 History of bus #7930 (modified to LPG in 1983)

The dynamometer data measured by OC Transpo at 41 mph (1500–1550 rpm) and compared with the data of the LPG bus measured under the same conditions:

Date		Measured power Fan off	Parasitic Power Position "drive"	Parasitic Power Position "neutral"	Overhaul required
4.10.79	DIESEL	94	99	45	
27.6.80		75	103	31	x
15.8.80		70	100	29	x
23.3.81		80	80	25	
2.6.81		67	80	34	x
27.10.81		62	95	41	x
19.11.81		80	90	36	
19.4.82		82	82	28	
15.3.83		100	71	24	
7.2.84	LPG	95 (85 with fan on)	60–70	20–25	

1.2.4 Engine performance of GM diesel buses in the OC Transpo fleet

1.2.4.1 Comparison of relatively new buses

Bus No.	Date	Measured power fan off (hp)	Parasitic power "drive" (hp)	Parasitic power "neutral" (hp)
8231	29.3.82	104	70	24
	30.11.82	103	60	19
	23.11.83	89	65	25
8232	11.3.82	96	70	21
	14.9.82	96	75	18
	20.9.83	81	88	25
8233	3.3.82	95	75	26
	1.9.82	108	70	18
	22.9.83	92	72	24
8234	15.3.82	106	70	26
	23.2.83	74	95	30
8235	6.10.82	86	60	31
	2.12.82	103	60	21
	29.11.83	95	69	25
8236	18.2.82	96	80	25
	28.2.83	106	65	19
	22.12.83	102	67	21
8237	1.3.82	88	70	25
	25.2.83	89	73	24
8238	22.2.82	98	70	25
	20.10.83	103	74	26
8239	3.3.82	95	80	26
	13.8.82	93	70	20
8240	18.3.82	100	70	23
	27.8.82	106	70	22
	25.7.83	92	74	25
8241	16.2.82	65	75	24

11 buses 27 tests

SUMMARY:

Power output measured -	below 80 hp	2	test results
	between 80-89 hp	5	" "
	between 90-99 hp	10	" "
	between 100-106 hp	10	" "

1.2.4.2 Comparison of 42 buses 79 and 80 (same age as LPG bus)

Bus No.	Power at 41 mph (1500-1550 rpm), fan off (different tests)											Mean value*
7901	100	104	78	70	68							102
7902	84	94	85	97	96	92						91
7903	93											93
7904	98	84										91
7905	94	83	78	85								87
7906	92	95	105	93	97	85						94
7907	92	97	108	106	95	81	92	90				95
7908	80	67	80	75	65	76	76	77	70	72	65	80
7909	88	92	93	75	85	90						89
7910	86	95	86	70	82	75	90	92	67			88
7911	102	85	75	92								93
7912	62	92	80	88	89							87
7913	95	75	100	86	101							95
7914	88	105	73	82	80							88
7915	78	104	79	88	92							94
7916	81	79	78	84	84	84	80	83				82
7917	85	81	81									82
7918	80	88										84
7919	96	65	88	76	80							88
7920	84	103	70	90	83	90						90
7921	90	88	91	86	90	100						91
7922	79	77	89	83	85							86
7923	90	69	90	89	94	95						92
7924	80	104	90	90	94	81	79					90
7925	79	93	83	100	85	90	87	92	90	87		89
7926	80	105	104	105	96							98
7927	89	82										85
7928	81	82	83	83	89	80						83
7929	81	68	77	75	75	77						81
7930	80	100	82	94	75	67	62	83	80			86

1.2.4.2 continued

Bus No.	Power at 41 mph (1500-1550 rpm), fan off (different tests)							Mean value*
8001	93	80	95					89
8002	84	96	95	94				92
8003	104	82	92	88				91
8004	85	92	100					92
8005	104	97	97	84				95
8006	101	94	88					94
8007	96	94	93	85	85			91
8008	89	100						94
8009	96	90	84	102	88			92
8010	89	75	96	99	96	82	80	90
8011	100	86						93
8012	87	106						96

* Mean value of all tests above 80 hp, i.e. all values below 80 hp were rejected (buses were sent to repair).
Overall mean value of buses in operation (of 42 bus mean values): 90 hp

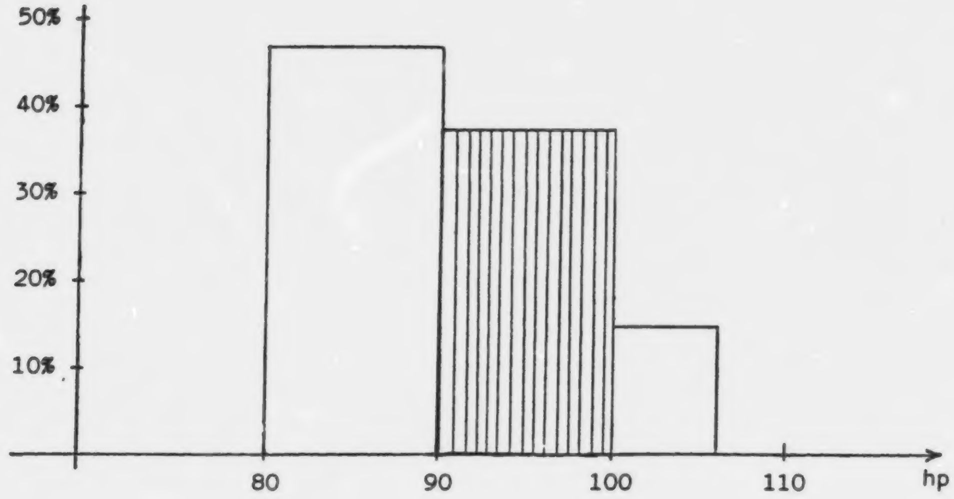
1.2.5 Summary

With a power output of about 90-95 hp on the dyno at 41 mph and an engine speed of about 1500 rpm, the LPG bus meets the given requirements according to the GM performance curve and meets the average performance of the OC Transpo diesel buses.

Statistics of all dyno-tests

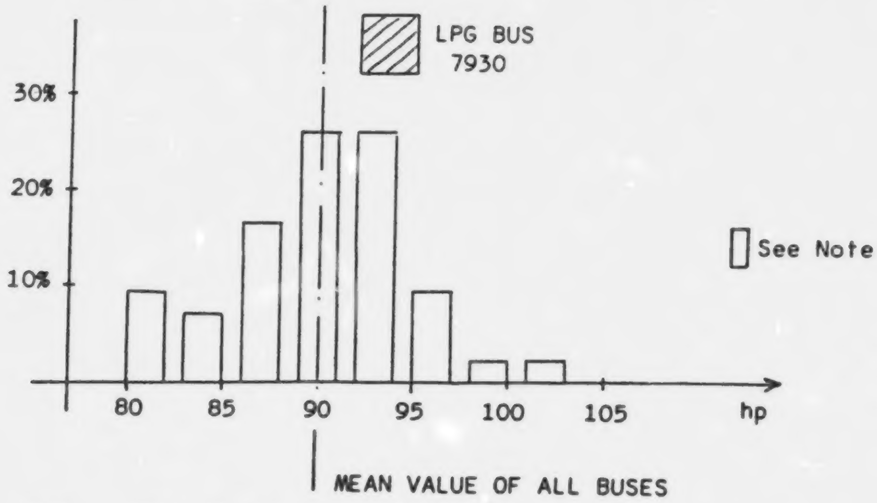
42 buses, total 170 test results (on buses with more than 80 hp)

between	80-89	hp:	47%
between	90-99	hp:	37.7%
between	100-106	hp:	15.3%



Statistics of the mean values of all 42 buses

42 buses = 100%



Note: This is the value of the exceptional bus reported in Section 1.2

2. PERFORMANCE TESTING

2.1 Basic data of diesel and LPG bus

For the comparison the following buses were used:

- Diesel bus: Number 8239
  Power on dyno at 41 mph: 98 hp (fan off)
- LPG bus: Number 7930
  Power on dyno at 41 mph: 90-95 hp (fan off).

2.2 Testing conditions

- Both buses were compared on two typical OC Transpo service routes:
  Route #1 - a city cycle (south city to north)
  Route #99: a suburban cycle (St. Laurent to Kanata, partly on Queensway).

- The buses stopped at every official bus stop for 10 seconds (#1: 80 stops, #99: 31 stops) and the number and time of the additional stops (for light, etc.) were recorded.

- The distance was measured by a hub-meter.

- All tests were carried out on Sunday, February 20, 1984. There was little traffic on the road and traffic effects on the tests were negligible.

2.3 Test results

2.3.1 Performance city cycle Route #1

		DIESEL	LPG
Official stops (10 sec.)	Nr.	80	80
	time	13 min. 20 sec.	13 min. 20 sec.
Additional stops	Nr.	29	27
	time	7 min. 8 sec.	6 min. 35 sec.
Total time		62 min. 20 sec.	61 min. 57 sec.
Total time without additional stops		55 min. 12 sec.	54 min. 22 sec.
Total time without all stops		41 min. 52 sec.	41 min. 2 sec.
Measured length of cycle #1		15.5 km	15.9 km
Average speed		22.21 km/h	23.04 km/h

2.3.2 Performance suburban cycle Route #99

		DIESEL	LPG
Official stops (10 sec.)	Nr.	31	31
	time	5 min. 10 sec.	5 min. 10 sec.
Additional stops	Nr.	25	24
	time	5 min. 3 sec.	4 min. 50 sec.
Total time		51 min. 36 sec.	51 min. 17 sec.
Total time without additional stops		46 min. 33 sec.	46 min. 27 sec.
Total time without all stops		41 min. 23 sec.	41 min. 17 sec.
Measured length of cycle #99		29.2 km	29.8 km
Average speed		42.3 km/h	43.3 km/h

3. SUMMARY/CONCLUSIONS

- It is concluded that the cooling system is adequate for both winter and summer use, but may be further improved by the small changes recommended in this report.

- It is concluded that the propane bus meets the power-performance levels specified by OC Transpo in its purchases of diesel-powered GM buses. Also the propane bus meets or exceeds the average power-performance levels measured by OC Transpo in its bus fleet.

- It is concluded that the road performance of the propane bus is equivalent to that of an average to above-average diesel bus from the OC Transpo fleet.

W. Jenkins - Project Manager
R.F. Webb - Consultant
M. Signer - Dereco Project Engineer

TECHNICAL REPORT #2 21.3.84

PROPANE BUS DEMONSTRATION

REPORT ON FUEL ECONOMY TESTS OF THE OC TRANSPO LPG-ENGINED CITY BUS

CONTENTS

1. COMPARATIVE FUEL ECONOMY TESTS: PROPANE AND DIESEL POWERED BUSES

1.1 The Go/No-Go Test Procedure
1.2 A Summary of the Results of the Modified Go/No-Go Tests
  1.2.1 Propane Bus #7930
  1.2.2 Diesel Bus #8239
  1.2.3 Fuel Utilization Ratio
  1.2.4 Recommendation on the Go/No-Go Test

2. OTHER OBSERVATIONS ON FUEL ECONOMY AND PERFORMANCE

2.1 Road Tests of #7930 - the Propane Bus
2.2 A Cost Comparison for Propane and Diesel Buses

1. COMPARATIVE FUEL ECONOMY TESTS: PROPANE AND DIESEL POWERED BUSES

1.1 The Go/No-Go Test Procedure

Schedule C of the contract between OC Transpo and the Ministry of Transportation and Communications provides a basis for the comparative testing of the fuel consumption of the first propane bus, the standard GM diesel bus and a bus powered by the IVECO 4-cycle diesel engine.

In view of the short time available for the acceptance tests the Steering Committee approved a modified Go/No-Go test procedure and the substitution of the DND test track at the Land Engineering Test Establishment (LETE) which is close to Ottawa, for the test track at Blainville, Quebec, use of which had been arranged with Transport Canada.

The key features of the Go/No-Go test which was run at LETE in the period 5-15 March 1984 were:

1. the comparative tests were conducted using the propane bus (#7930) and "an average" diesel bus (#8239) both of which were used in the previous tests (see Technical Report #1 dated 19.2.84) involving dynamometer testing of the engines and comparative road performance testing. The testing of the IVECO 4-cycle diesel engine has been deferred.

2. the requirement for testing of the fuel consumption of the propane bus and the comparable diesel bus for 30 days in revenue service was excluded from the Go/No-Go test requirement, it being considered that the carefully controlled track tests of fuel consumption would be precise and sufficient.

3. MTC personnel reviewed the the test procedure to fit the LETE track which is 1.75 miles long compared to the 2 mile length described in Schedule C of the contract for the Advanced Design Bus (ADB) duty cycle of tests. The fuel consumption of each bus was determined by weighing the fuel tank before and after each cycle which comprised operating each bus over 7 laps of the test circuit (12.23 miles) during which time each bus was made to simulate the conditions found in city service, arterial service and commuter service by control of the number of stops and dwell time at each stop, acceleration and deceleration distances, cruise distance and top speed. Sufficient repeats of the test (5 for each vehicle) were made to minimize errors in averaging fuel consumption values.

1.2 A Summary of the Results of the Modified Go/No-Go Tests

1.2.1 Propane Bus #7930

Time tests using the ADB cycle conducted on 9 March 1984 showed an average fuel consumption of 20.22 lbs/cycle of 7 laps of 1.7473 miles and acceptable variation of fuel consumption (20.0 to 20.6 lbs/cycle, within the ±5% range specified). The specific gravity of the propane used was assumed to be consistent with the average of automotive grade (HD-5) propane used in Canada at 0.51. The fuel consumption averaged over the cycle distance of 12.23 miles was therefore 3.965 gallons giving a fuel economy value on propane of 3.085 mpg (91.4 L/100km).

1.2.2 Diesel Bus #8239

Five tests using the ADB cycle were conducted on 13 March 1984 and showed an average fuel consumption of 19.08 lbs of diesel fuel/cycle of 7 laps of 1.7473 miles (and a variation from 18.6 to 19.6 lbs/cycle, within the ±5% range specified). The specific gravity of the diesel fuel measured by the Fuels and Lubricants Laboratory of the National Research Council was 0.82. The fuel consumption averaged over the cycle distance of 12.23 miles was therefore 2.33 gallons, giving a fuel economy value of 5.256 mpg (53.65 L/100km).

1.2.3 Fuel Utilization Ratio

The contract specifies the Fuel Utilization Ratio (FUR) of propane compared to diesel fuel should not exceed 1.8.

The value found in the tests conducted at LETE was 1.7.

1.2.4 Recommendation on the Go/No-Go Test

The project manager and the consultant to the Steering Committee believe that the LETE fuel consumption test data, taken together with the experience on fuel use and operating behaviour of the propane bus in other tests in simulated service runs are a sufficient basis for the Go/No-Go decision. Their recommendation is that the Steering Committee accept the data as evidence that Dereco has met its obligations with respect to the fuel economy and operating specifications of the prototype engine and that the demonstration proceed to the next phase involving the procurement of 14 additional propane engines and operation of a 15 bus propane fleet.

2. OTHER OBSERVATIONS ON FUEL ECONOMY AND PERFORMANCE

2.1 Road Tests of #7930 - the Propane Bus

The fuel consumption of the propane bus #7930 was measured during the tests made on 20 February 1984 (see Technical Report #1) of the performance of the propane bus (#7930) compared to that of the diesel bus (#8239) on OC Transpo routes 1 and 99. The fuel consumption of the diesel bus used in the performance tests was not measured.

Over route #1, a city route of 9.88 miles with 80 bus stops each of 10 seconds duration and 29 additional stops for traffic, lights and other signs, the propane fuel consumption was 4.23 gallons giving a fuel economy of 2.34 mpg.

Actual city service may be more fuel efficient with fewer stops and shorter idle period (7 seconds).

Over route #99, a suburban route of 18.2 miles with 31 bus stops each of 10 seconds duration and 24 additional stops for traffic, lights and other signs, the propane consumption was 5.4 gallons giving a fuel economy of 3.37 mpg.

Again the 10 second idle and stop at all stops may not be indicative of true suburban service conditions.

2.2 A Cost Comparison for Propane and Diesel Buses

The recent costs of diesel fuel to OC Transpo have been in the range:

37.18 to 38.68¢/litre, equivalent to $1.69 to $1.76/gallon.

The anticipated range of contract prices for propane delivered in bulk to the OC Transpo fleet is:

20.50 to 21.50¢/litre, equivalent to $0.93 to $0.98/gallon.

Assuming fuel economy in service will be that determined from the ADB cycle tests at LETE:

diesel fuel economy 5.256 mpg; propane 3.085 mpg.

The anticipated cost comparisons are:

diesel fuel cost, cents per mile:	32.19 to 33.43
propane fuel cost, cents per mile:	30.15 to 31.62

W.D. Jenkins
J.E. Turner
R.F. Webb

TECHNICAL REPORT #4

PROPANE BUS DEMONSTRATION

29.9.84

CONTENTS

1. NOTES ON RECONVERSION OF PROPANE BUSES TO DIESEL OPERATION

1.1 Rationale
1.2 Past Experience
1.3 The Vehicle Reconversion Operation
1.4 Site Changes Necessary for Reconversion
1.5 In-Garage Changes
1.6 Possible Strategy for Conversion

2. NOTES ON PROPANE ENGINE DEVELOPMENTS

2.1 Modification to the Dereco Propane Engine
2.2 Longer Term Developments
2.3 A Perspective

1. NOTES ON RECONVERSION OF PROPANE BUSES TO DIESEL OPERATION

1.1 Rationale

The reconversion of the OC Transpo propane buses to a diesel operation may be required if the performance or economics of the propane system prove to be unsatisfactory, or the use of a small propane fleet proves to be incompatible with a large diesel fleet. Dereco's engines were claimed to be reconvertible.

1.2 Past Experience

Dereco converted the trial propane buses used by the city of Basel in Switzerland and one bus used in intercity and mountain service by the Swiss Postal Service. The diesel buses are now in regular service and no change has been reported in the diesel fuel economy or bus performance compared to engines that have not been subject to interim use as propane engines. The data reported by Dereco on fuel economy of the Basel city buses are:

	Volume Basis L/100 km	Energy Basis MJ/100 km
LPG (80%-60% propane, remainder butane) bus operation	78.1	1830
Diesel (before and after conversion from 30,000 km on propane)	48	1618-1689
Ratio LPG/Diesel consumption, Basel	1.63	1.13-1.08

1.3 The Vehicle Reconversion Operation

Dereco reports that no work is required on the basic engine if conversion to diesel is required, but the original engine conversion for reverse rotation limits automatic engine governing. In the diesel retrofit case this would mean a small increase in diesel fuel consumption at maximum power ratings compared to the standard anti-clockwise rotation engine. The fuel economy of the reverse rotation 4-cycle diesel engine is expected to be superior to that of the 2-stroke GM engine. The conversion from propane to diesel may increase the rated power of the engine by 10% (to 210-215 HP), but will reduce the high torque rise to conventional diesel engine levels.

Dereco advises that the changes required for the engine conversion involve:

a. The replacement of the pistons to provide the higher compression ratio needed in the diesel engine.
b. An addition or modification to the cylinder head to permit mounting of the standard diesel fuel injectors, valves and valve inserts in place of the spark plug.
c. Replacement of the ignition distributor and speed governor of the LPG system by the standard Bosch injection pump.
d. Removal of the fuel ignition and LPG fuel system (carburetor, vapourizer, filter fuel lock) and change of the intake manifold and regulation system.

The total conversion time for the engine is estimated at not greater than 10 hours (including diesel engine testing on the dynamometer). The Dereco quotation for the parts supplied for the conversion in 1984/5 is $4,000 Canadian. It is to be noted that the changes made by OC Transpo and Dereco to interface the 4 cycle Iveco engine with the GM bus will not require replacement. Thus the engine/gear box interface, flywheel, clutch modifications, the alternator support and alternator belt drive, the cooling fan assembly, engine supports will not require replacement.

Replacement will be required by OC Transpo of all piping and connections specific to propane (these are now being drawn by OC Transpo and Hovey Associates for the diesel to propane conversion pathway).

The present conversions of the GM diesel buses to propane involve the addition of the propane storage tanks to the bus while the diesel tanks, though empty, are retained. A further task for OC Transpo in the reverse process of conversion from propane to diesel will therefore be to purge the propane tanks free of propane and to remove the 4 cylinder manifolded propane fuel tank assembly from the bus. A safety procedure for the removal and disposal of propane fuel tanks has been described by the U.S. National LP Gas Association. Since the propane fuel tank is specifically designed for the GM bus, it will have only scrap value. No significant value can be credited to other propane components (such as the carburetor-vapourizer system involved in the retrofit) unless they are utilized within the remainder of the OC Transpo propane fleet (the automobile service fleet, for example).

1.4 Site Changes Necessary for Reconversion

The propane fuelling station and propane bulk storage facilities installed for the period of the demonstration involve a minimum outlay by OC Transpo on construction, piping and safety-related hardware. The propane supplier, Superior Propane, has assumed the cost of installing two 2000 Imperial gallons bulk fuel storage tanks and the propane bus fuelling equipment for the period of the demonstration.

OC Transpo is currently designing, and will receive quotations on, its part of the fuel system installation which will include:

- the foundation, electrical wiring and connections and the overhead heating system for the bus fuelling island
- the foundation (grading) electrical wiring and connections for the bulk storage tanks on site
- the construction of the trench required for fuel movement by pipe from bulk storage to the fuel island
- pipework and grills associated with the propane pipeline on site
- any changes to the roadway needed to move propane onto the site.

An estimate of the write-off in the event of discontinuance of propane fuelling will be available in November. The budget allocated for the fuelling (excluding contingencies) was $60,300 plus a share of the budgeted $43,000 for architectural and drafting work. Actual expenditure will be less, due to the contract terms negotiated with Superior Propane.

1.5 In-Garage Changes

The changes in the garage made to accommodate propane bus garaging and maintenance and the testing of propane buses will be written off. These were budgeted as follows:

Explosion proofing, safety equipment	$8,500
Test equipment	6,000
Miscellaneous engineering and office equipment	3,000
	17,500

1.6 Possible Strategy for Conversion

Should it be necessary to discontinue the use of propane in OC Transpo buses, it is suggested that the site and fleet be reconverted as rapidly as possible to diesel and the Iveco engines retained for use in their diesel configuration. The engines would be subsequently cannibalized for parts as required to the maximum extent feasible to maintain the special diesel fleet without purchase and maintenance of an additional inventory of engines or major components.

Off-site vehicle conversion to diesel may be a preferred method to avoid safety hazards, to expedite the conversion and disposal of unwanted (scrap) tanks. No provision should be made for storage of propane-specific parts for subsequent reconversion to propane.

The fuel storage facility and refuelling facility should also be dismantled promptly. The fuelling of the remaining service truck automobile fleet will be continued at the Belfast site: transfer of their fuelling operation to the St. Laurent site would not be beneficial.

2. NOTES ON PROPANE ENGINE DEVELOPMENTS

2.1 Modification to the Dereco Propane Engine

The engine test program at UTDC will provide a basis for measurements of fuel economy and performance improvements possible with the Dereco engine beyond those investigated at OC Transpo which have already improved the fit of the engine in the bus, power output and operability.

The Dereco engine can be further optimized by:

a. improving the crankability of the starter: the cranking RPM may be the cause of reported hard starting
b. replacement of the spring-over vacuum type engine governor with an electronic governor to reduce the wandering that now occurs, i.e. the governor is inadequately optimized for the service required
c. an increase in the compression ratio of the engine by use of new pistons (a series is available for testing). The present engine compression ratio (10.9:1) was designed to operate without knock on LPG with up to 40% butane content. An increase of 1 unit in the compression ratio may be acceptable when used with HD-5 propane and the change is likely to increase propane fuel economy by 2-2.5% with no loss in power or torque.

2.2 Longer Term Developments

The Dereco propane engines for city bus service are naturally aspirated and an increase in peak power output and propane fuel economy could be achieved by the development of a turbocharged version of the Dereco engine. M.A.N. has developed a turbocharged pancake-type propane engine which will be introduced into the articulated buses used in Vienna, and the Cummins Gas Engine Company is developing a turbocharged propane version of the Cummins Big Cam engine series for highway truck use. The impediment at Dereco to the development of the turbocharged version is time and money needed to develop and test the added cooling system needed in a turbocharged propane engine.

A major development in the propane engine series which is under consideration at Dereco is the production of a direct fuel injection spark ignition engine that is expected to improve cold start and fuel economy attendant upon the removal of the throttle losses and the carburetion system. Engine response and peak power output can also be improved with the direct injection system.

Another significant opportunity available with the propane engine that has not been exploited is a simplification of the gear box. The high drive-off torque (max. torque achieved at 600 rpm for propane versus 1100-1500 rpm for max. torque in the diesel versions) and increased full speed range of the propane engine mean that the propane bus could be operated without gear change at speeds between 22 and 106 km/hour (13-65 mph). A simple low cost, low maintenance manual or automatic gearbox could be developed.

2.3 A Perspective

The major drawbacks to the propane bus are not related to the engine performance or fuel economy, but in the areas of fast fuelling, fuel loss in filling the vehicle (safety hazard), fuel overfill (with attendant safety problems when cold fuel expands and vents in the parking garage) and the size and weight of the in-vehicle propane storage tanks needed to provide the same autonomy as the diesel engine. The solution of these problems and the optimization of the present engine configuration will make an earlier and greater impact on OC Transpo and other fleet response to propane than the longer term and high cost investigations of turbocharged and direct injection engines and gearbox developments.

Another development that will become important in the future is the reduction of the nitrogen oxide emissions of propane engines. The Exhibit shows the current status the Dereco propane bus engine. Impco (the major propane carburetor manufacturer located in California) will shortly offer a pollution control device designed for automobiles and small trucks operated on propane.

Exhibit

Examples of Pollution Legislation in Canada and U.S.
For Heavy Duty Vehicles
(in grams per brake HP hour)

	Hydrocarbon(HC)	NOx	CO	Smoke(%opacity)
CANADA CURRENT				
Diesel & gasoline engines	HC+NOx combined=16		40	20/15/50 (1)
U.S. FEDERAL 1985				
Diesel engines	1.3	10.7	15.5	20/15/50 (1)
Gasoline engines	1.9	10.6	37.1	
Propane engines	As for gasoline engines			
CALIFORNIA, 1984+				
Diesel and gasoline	0.5	4 (2)	25 (3)	
REPORTED BY DERECO				
8220 Propane	0.78	12	1.7	
8220 Propane (2)	0.75	9.3	1.8	

Notes: (1) At acceleration, lug and peak power
(2) With some sacrifice of fuel economy
(3) Hydrocarbons plus NOx not greater than 4.5 is the standard

18 February 1985

TECHNICAL REPORT #5
PROPANE BUS DEMONSTRATION

PROPANE AS A BUS ENGINE FUEL

A Progress Report on the OC Transpo
Propane Demonstration Project

Comprising Three Papers
Presented to the Engineering Division
of the
Canadian Urban Transit Association
at the Skyline Hotel
Ottawa, 21 November 1984

PAPER #1 "ORGANIZATION OF THE OC TRANSPO PROPANE DEMONSTRATION"

by P.J. Newgard, Equipment Manager, OC Transpo

1. Introduction

In 1981 OC Transpo became aware of other Canadian efforts at fuel substitution in the heavy duty transportation area. Because of rising diesel fuel prices and Canada's "off-oil" objectives we decided to investigate this area. In discussions with the Canadian Trucking Association, the federal department of Energy, Mines & Resources and the Ontario Ministry of Transportation and Communications, we found a strong mutual interest in investigating alternative fuels for Canadian transit buses.

A great deal of current and past information was available, both on alternative fuels in transportation use, and alternative power systems for buses. Most notably Chicago Transit and several other American and Canadian transit properties had operated LPG bus fleets during the 1950's and 60's with modified heavy duty gasoline engines. However, by 1981 the only bus fleets with heavy duty engines operating on alternative fuels were in Vienna and Amsterdam: there was essentially no similar work going on in North America with heavy duty engines.

With funding from the federal department of Energy, Mines and Resources we undertook an initial investigation. After reviewing the non-petroleum alternatives to diesel fuel (CNG, LNG, propane and methanol), we found that LPG (i.e. propane) was the best developed and least experimental alternative available. We unfortunately also confirmed that our 2-stroke diesel engines could not practically be converted to spark-ignition and propane. That meant we would need a new engine if we wished to retrofit existing buses to propane. The cost of conversion was a problem, but we were advised that this could be overcome by joint funding from the Ontario and federal governments if we would undertake a large-scale propane demonstration under the Conservation and Renewable Energy Demonstration Act (CREDA), a component of the National Energy Program.

As part of the initial study we visited companies active in the development of propane bus operations: Amsterdam Transit, the Dutch Road Research Laboratory, M.A.N. in Germany, and Dereco in Switzerland. Based on diesel and propane fuel consumptions demonstrated in Europe an economic analysis was completed, which indicated operating cost savings were possible in our operations from conversion to propane.

One important consideration during the initial study was safety. Propane systems require garage facilities and procedures that are not needed for diesel. Most notably, monitoring equipment must be installed along with explosion-proof electrical equipment (similar to a paint booth) and increased forced air exhaust. We concluded that the safety precautions were reasonable and within our capacity, at least in terms of running a demonstration project, and certainly the operating economics could probably be realized. We therefore entered into a demonstration agreement with the federal department EMR and the Ontario Ministry of Energy under the CREDA program. The objectives of the demonstration project are to

- retrofit a number of existing buses with propane systems and gain practical operating and maintenance experience for the transit industry
- carry out safety modifications to buildings for the storage and maintenance of the vehicles
- study fuelling systems for buses, bearing in mind safety and efficiency
- provide a visible demonstration of another "off-oil" initiative for both the federal and Ontario governments.

Specifically the project will

- last for 3 years
- purchase 15 propane engines
- purchase one 4-stroke Iveco diesel engine otherwise identical to the propane to provide a measure of fuel cost savings from propane and those which may be attributed to the 4-stroke engine replacing the standard 2-stroke
- purchase newly designed on-bus propane tanks to suit the space available and capacity needed
- provide new bulk propane fuelling facilities.

A fourth party, the Ontario Ministry of Transportation and Communications has been added to the management of the project because of its in-depth involvement with buses in Ontario and also in alternative fuels. MTC will administer the transfer of funds to OC Transpo and advise on the program.

Exhibit 1 shows the organization we have established for the demonstration, the key element of which is the Steering Committee set up to guide the program and represent the interests of all parties, although OC Transpo retains full responsibility for the project and the operation of the buses.

2. Engine Acquisition

We invited bids on supply of propane engines from all North American manufacturers of heavy duty highway diesels and from selected European companies with diesel/propane experience. The contract issued was for the supply first of only one propane engine for a GO/NO-GO demonstration, to be followed, if successful, by purchase of 14 more. Assistance in the re-engining of the 15 bus fleet was required, together with training for the retrofit and service.

No North American supplier was interested in the contract at that time and, accordingly, a contract was awarded to Dereco of Switzerland, which is majority-owned by FIAT. Since Dereco had extensive background in engine development and had converted a number of diesel engines supplied by FIAT's Iveco division to propane, Dereco met the specifications we had set, which required a close match of power, acceleration and fuel economy set at a maximum level such that propane costs did not exceed diesel costs.

The main problems all manufacturers have with the bus engine replacement are the

- small size of the engine compartment available
- unique rotation direction of the GM engine (counterclockwise)
- location of carburetion, ignition and other major accessories on the "wrong" side of the engine
- need for an adapter between their engine and the Allison transmission.

We paid a modest premium for these engines as they were from a limited production run. In series production, however, the propane engine may be cheaper than the current diesels, since the high-cost injection system of the conventional diesel is replaced by a lower cost carburetion and spark-ignition system.

3. Fuel Supply

We invited proposals from major suppliers to provide propane fuel together with storage and refuelling facilities for the period of the demonstration. The supplier was asked to provide assistance with the choice and installation of the bulk fuel storage tank, the refuelling station and the process of obtaining local and provincial government approvals. An attractive price for fuel has been obtained and the fuel station is being designed.

4. Safety

One of the major problems with propane is the perception of safety. We have examined the 400-plus bus operation in Vienna in great detail and are basing our garage changes and procedures on their experience. Separate from this project, and with Transport Canada funding, we have now completed a reference manual on propane safety covering the installation and operation of the fuel storage and fuelling facilities, staff training, engine conversions, maintenance, inspection, vehicle storage and operation of a propane bus fleet. Exhibit 2 illustrates the factors involved in our propane safety considerations.

5. Staff Training

An important part of the demonstration is the training of staff. We have now completed certification of personnel responsible for the installation of the propane systems in the fleet. 29 out of 30 of our staff tested have been awarded S6A certification for the installation of propane equipment in the buses. Some will be certified to inspect and certify the converted buses and others trained for the refuelling operations. Drivers are also to be given instruction on the steps necessary in the event of accidents or propane leaks, but no driving retraining is required for the propane bus.

6. Project Schedule

Exhibit 3 shows the current schedule established for the project. Together with operating the buses we will be closely monitoring the safety aspects of the vehicles and their compatibility with our overall maintenance operation. At the end of the project a complete report will be issued through MTC and decisions will be taken on continuing the propane operation, or converting back to diesel.

Exhibit 1

ORGANIZATION FOR PROPANE DEMONSTRATION

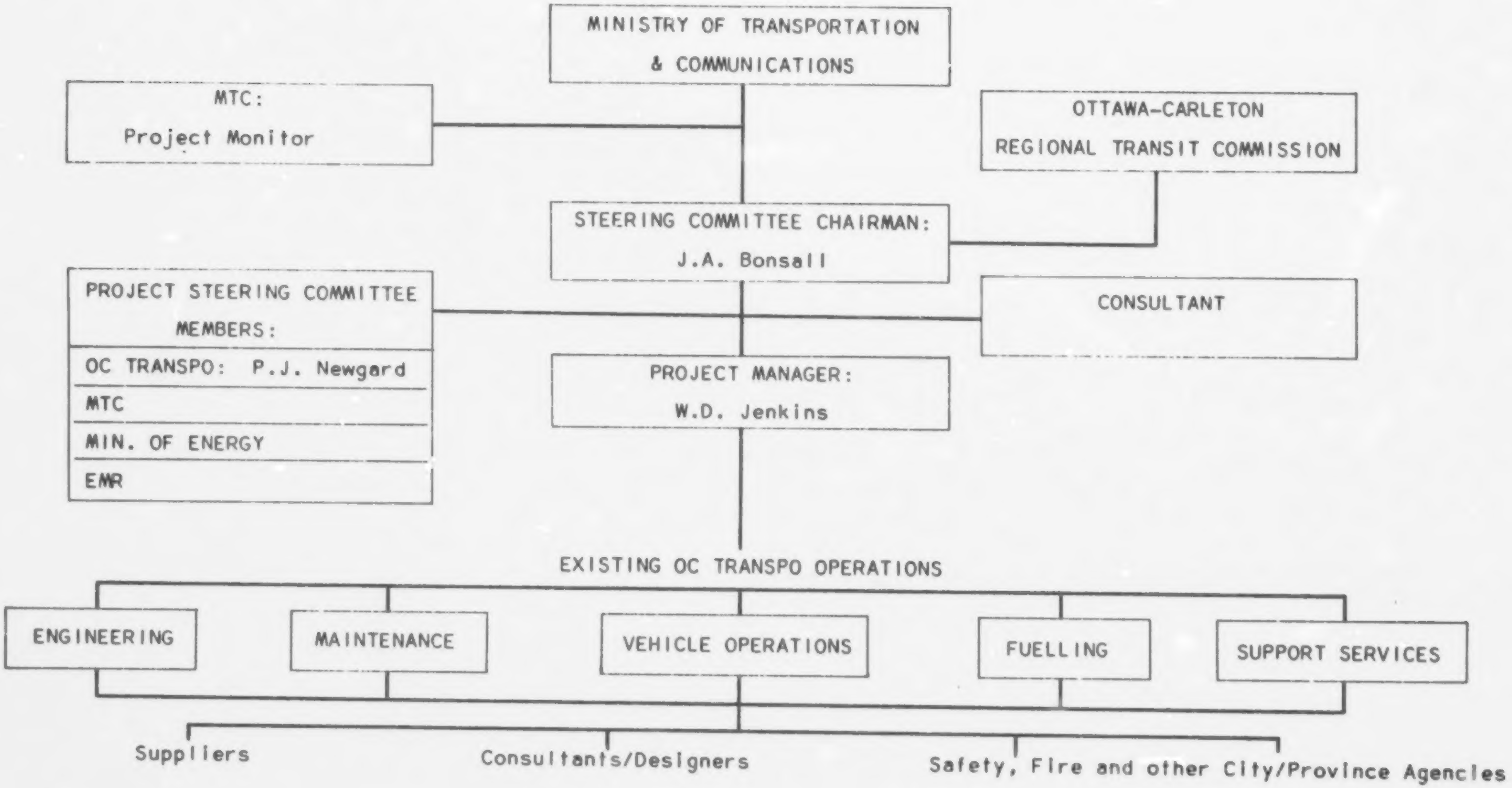
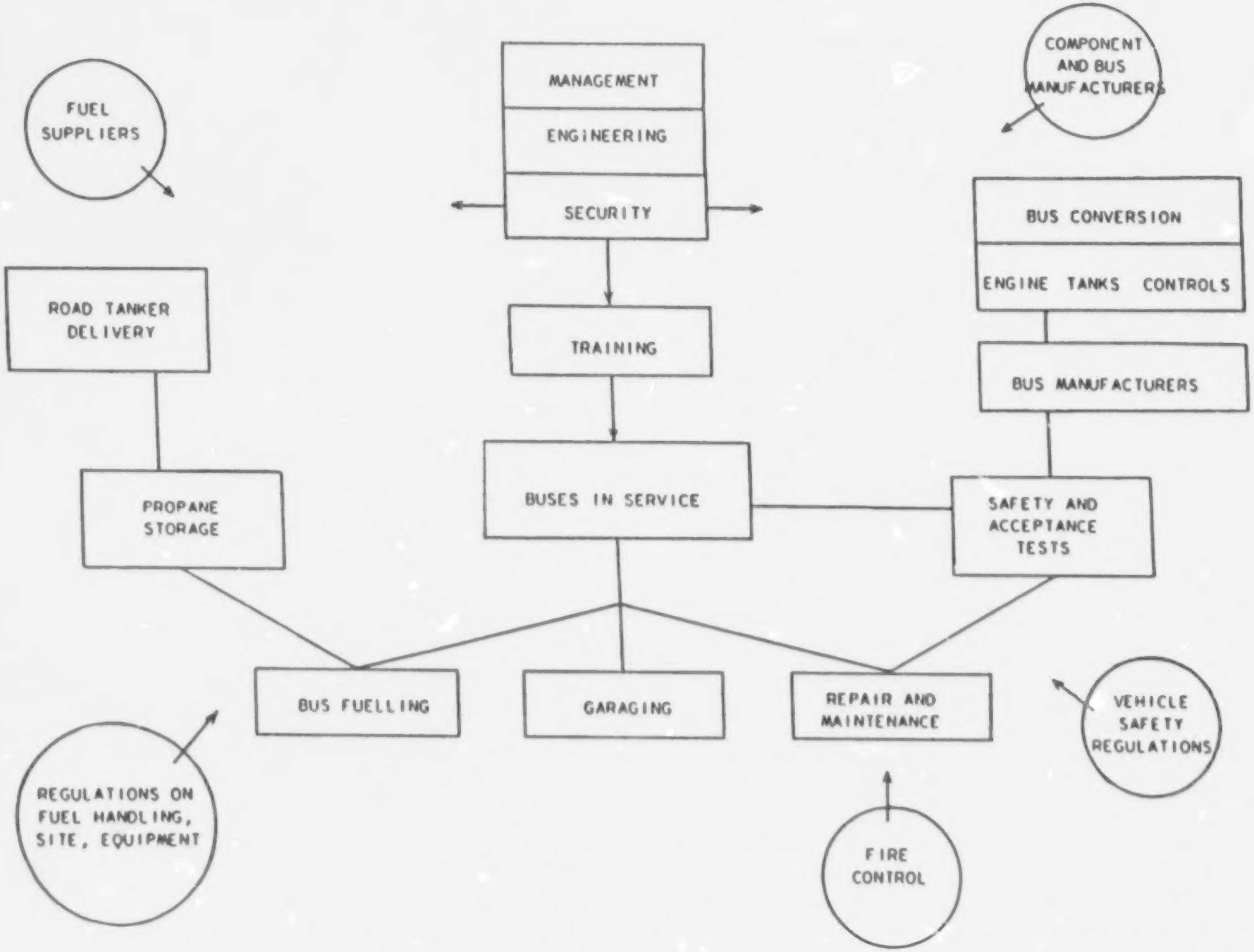

MINISTRY OF TRANSPORTATION & COMMUNICATIONS
MTC: Project Monitor
OTTAWA-CARLETON REGIONAL TRANSIT COMMISSION
STEERING COMMITTEE CHAIRMAN: J.A. Bonsall
PROJECT STEERING COMMITTEE MEMBERS:
OC TRANSPO: P.J. Newgard
MTC
MIN. OF ENERGY
EMR
CONSULTANT
PROJECT MANAGER: W.D. Jenkins
EXISTING OC TRANSPO OPERATIONS
ENGINEERING
MAINTENANCE
VEHICLE OPERATIONS
FUELLING
SUPPORT SERVICES
Suppliers
Consultants/Designers
Safety, Fire and other City/Province Agencies

Exhibit 2

COMPONENTS OF THE PROPANE BUS SYSTEM


FUEL SUPPLIERS
MANAGEMENT
ENGINEERING
SECURITY
COMPONENT AND BUS MANUFACTURERS
BUS CONVERSION
ENGINE TANKS CONTROLS
ROAD TANKER DELIVERY
TRAINING
BUS MANUFACTURERS
PROPANE STORAGE
BUSES IN SERVICE
SAFETY AND ACCEPTANCE TESTS
BUS FUELLING
GARAGING
REPAIR AND MAINTENANCE
VEHICLE SAFETY REGULATIONS
REGULATIONS ON FUEL HANDLING, SITE, EQUIPMENT
FIRE CONTROL

PAPER #2 "THE RATIONALE FOR THE PROPANE BUS DEMONSTRATION"

by R.F. Webb, Technical Consultant to OC Transpo

1. Introduction

At the moment, the only oil crisis we hear about is that which exists among producers of crude oil who are struggling to maintain prices in a market glutted with surplus crude oil capacity. However, when we began the investigation of propane use at OC Transpo in 1982, diesel had been in short supply and prices were increasing, after having already increased eight-fold since 1973. It was then estimated that the Commission's annual bill for diesel fuel in 1985 would be over $11 million, accounting for over 12% of the operating budget. This prediction has proved true, and no return to the easier days of low cost, high quality diesel fuel is likely.

Throughout Canada the total diesel fuel consumption for 10,500 or so city buses in active service is reported by the Canadian Urban Transit Association to be in the range of 330 million litres/year, so cost increases or supply shortages will have a significant impact. As shown in Exhibit 1, the impact will be greatest in the 6,000 or so transit buses operated in the largest cities which, due to traffic and routing conditions, have higher fuel consumption than buses in smaller city fleets.

2. Diesel Fuel Supply Quality and Price Problems

The problems facing city bus fleets in the future are summarized in Exhibit 2. Although there is a surplus of crude on the international markets, Canada is, and will continue to be, a net importer of crude throughout this century. Bus fleet operators will therefore be dependent upon diesel, based in part upon imported crudes from

Exhibit 3

DEMONSTRATION SCHEDULE

```
                                                     1984       |          1985         |       1986
                                             M A M J J A S O N D|J F M A M J J A S O N D|J F M A M J J A
                                             ------------------------------------------------------------
1.  Test first engine                                 x------x                                : 
                                             x-------xRework fuel system                      :
                                                                                              :
2.  GO/NO GO decision                        x                                                :
3.  Acquire, convert 14 units                                  x---x                          :
4.  Revise vehicle fuel system               x-----x x-x                                      :
5.  UTDC tests                                          D    P                                :
                                                     x---x x---x                              :
6.  Inspection, acceptance criteria,                                                          :
    vehicles                                       x---x                                      :
7.  Fixed fuelling design, analysis                     x----x                                :
8.  Garage revisions                                    x----------x                          :
9.  Data collection system              x-----------------------------------------------------x--------x
10. Training, safety programs              x-x      x----------x     x--x       x--x      x--x: x--x
11. Operations on propane                    1             2  8                     15        :   ?
                                        x--------------x x-x x-x x----------------------------x--------x
12. Inspections of engines/                                                                   :
    vehicles                                   D    P        P        P        P      P       P+D   P
                                              x--x x--x    x---x     x--x     x--x   x--x     x--x x--x
13. Passenger & driver surveys                                 x---x            x--x          x---x
14. Reports:  Quarterly to                                                                    :
    Steering Committee                       x           x     x     x     x     x     x     x:    x
            Technical                         x            x                                  :
                                             1,2          3,4                                 :
15. Final Report                                                                              :      x
16. Publicity                                  Documents   CUTA
                                                x------x    x--x                                x----x
```

unreliable suppliers who will increase prices as soon as the current production surplus is worked off: this may be as early as 1988-9.

Diesel fuel is the heart cut of the barrel and the amount of bus quality #1 grade diesel that can be produced from a barrel of crude oil is limited. Diesel demand is forecast to grow steadily in the future, even though gasoline growth will continue to be zero or negative as more fuel-efficient cars are bought and begin to predominate in the stock on the highway. The #1 grade of diesel is best formulated using a proportion of high cetane kerosene, which is also in demand as a jet aircraft fuel. This grade of diesel is also that needed in diesel-powered automobiles and for trucks operating in the North in winter. There is a unanimous view among forecasters that shortages of high quality diesel fuel will occur in the future, especially if crude oil throughput at Canada's refineries is curtailed by a continued lack of growth in the gasoline market.

Another factor that affects the use of diesel fuel in city buses is quality. The world refineries are adjusting slowly to the heavier grades of crude oil that are available and to the use of the heaviest portion of the crude oil barrel (the so-called residuals or bunker oils formerly used as a fuel in electric power plants when prices were low and high sulphur fuels were tolerated) as sources of the lighter transport fuels.

The use of these heavy crudes particularly affect the combustion quality (measured as cetane number) of diesel fuels. In Canada the problem is heightened by the need here to use more of the heavy crudes found in Saskatchewan and Alberta and the use of the heaviest oil of all - the tar sands material. The quality of Canada's diesel fuel is therefore expected to deteriorate while supplies will not keep pace with the growing demand. Some changes can be made in the refineries to offset this supply/quality deterioration and Shell, for example, at

Scotford in Alberta has a new refinery just coming on stream which can, in theory, process a diet of 100% heavy crude or tar sands-based synthetic crude oils. These upgrading facilities increase the cost of diesel fuel production, which costs must be passed on to users such as the city bus properties, particularly where they are unable to use lower (cetane) quality fuels for environmental reasons.

A summary of this dilemma of the need for crude imports, the diesel supply/demand problem is given in Exhibits 3,4,5 and 6.

Exhibit 4 illustrates the problem of the continued crude oil import requirement which will result in an increase in Canada's oil import bill from $3 billion/year in 1984 to $3.4 billion (in 1984 dollars) by the year 2000, even if good success attends the effort to produce more of the nation's oil requirement. Exhibit 4 also shows that the demand for diesel fuel is expected to increase by 35% or so in the next 10-15 years, that diesel costs will increase (see Exhibit 5) in today's dollars by about the same percentage, while the fuel quality deteriorates.

Exhibit 6 gives the current and expected future (1990) diesel fuel specifications and average qualities. The change in ignition quality (cetane number) will affect cold start and may lead to increased engine knocking, but this will affect trucks more than buses. The really important changes that will accompany fuel quality deterioration lie in the increased engine corrosion and acid components in the exhaust, arising from higher sulphur-containing fuels and the increase in smoke and particulate emissions which will accompany use of high-boiling, low-cetane fuels. These can be reduced, but only by the incorporation of filters and other devices in the engine exhaust which will increase the complexity of bus operations and maintenance and the purchase price of diesel buses.

2. Pollution Control

The combined effect of higher bus costs and lower fuel quality may be only part of the pollution problem in the future. It seems certain that pollution control legislation will be tightened in Canada to U.S. levels and that these levels will be paced by the stringent pollution control legislation and standards set for California. Bus exhaust pollution is certain to be an issue within this decade and the changes foreseen in diesel fuel quality will complicate the adjustments required. In addition, it is anticipated that noise control in city environments will be another area of active legislation in the decade ahead: it is already an issue in Europe.

3. Possible Solutions and the Propane Option

Exhibit 7 shows the problems and some expected responses. Engines will certainly need to change in the future to meet fuel economy, fuel cost and pollution legislation, but changes in the fuel will also be necessary to meet the difficult targets that are even now being set. One way to change the fuel is to formulate it with additives; another is the more radical route involving replacement of diesel by lighter fuels, particularly those based upon natural gas, such as compressed or liquid natural gas or propane.

OC Transpo has chosen to evaluate propane since the technology of propane use in city buses has been demonstrated on a large scale in Europe with modern engine designs, and an infrastructure for propane delivery is available. Furthermore, as shown in Exhibit 8, propane is in large surplus supply in Canada and is expected to remain so throughout the period to 2000, certainly in sufficient quantity to meet any level of demand that might be created for city bus use.

The change to propane (see Exhibit 9) is expected to provide a number of benefits in addition to reducing our dependence on imported oil. The benefits include a reduction in the cost of fuel due to the low price of propane relative to diesel fuel, which exists despite the higher volumes of propane that must be used.

In Ontario there are further cost savings through tax concessions provided by the Ontario government. There is no road fuel tax on propane in Ontario at the moment. In addition, new buses (and other vehicles) are exempt from the provincial sales tax if they are manufactured to operate on alternative (non oil-based) fuel, such as propane, compressed or liquid natural gas, or even methyl alcohol.

The propane buses are significantly quieter than diesel-engined buses, and the level of noxious exhaust emissions is reduced. There is a particularly noticeable absence of particulates and smoke in the exhaust, and the sometimes objectionable odour of the diesel exhaust is also absent.

A bonus noted in Vienna and by OC Transpo drivers is the improved quality of the ride available with the propane-engined bus attributed in large measure to the high torque available at low speed (strong, steady, pull-away from rest), and the low level of bus vibration due to the different combustion regime which the spark-ignition propane engine provides in comparison with the conventional compression ignition (diesel) engines.

4. Cost Benefits from Propane

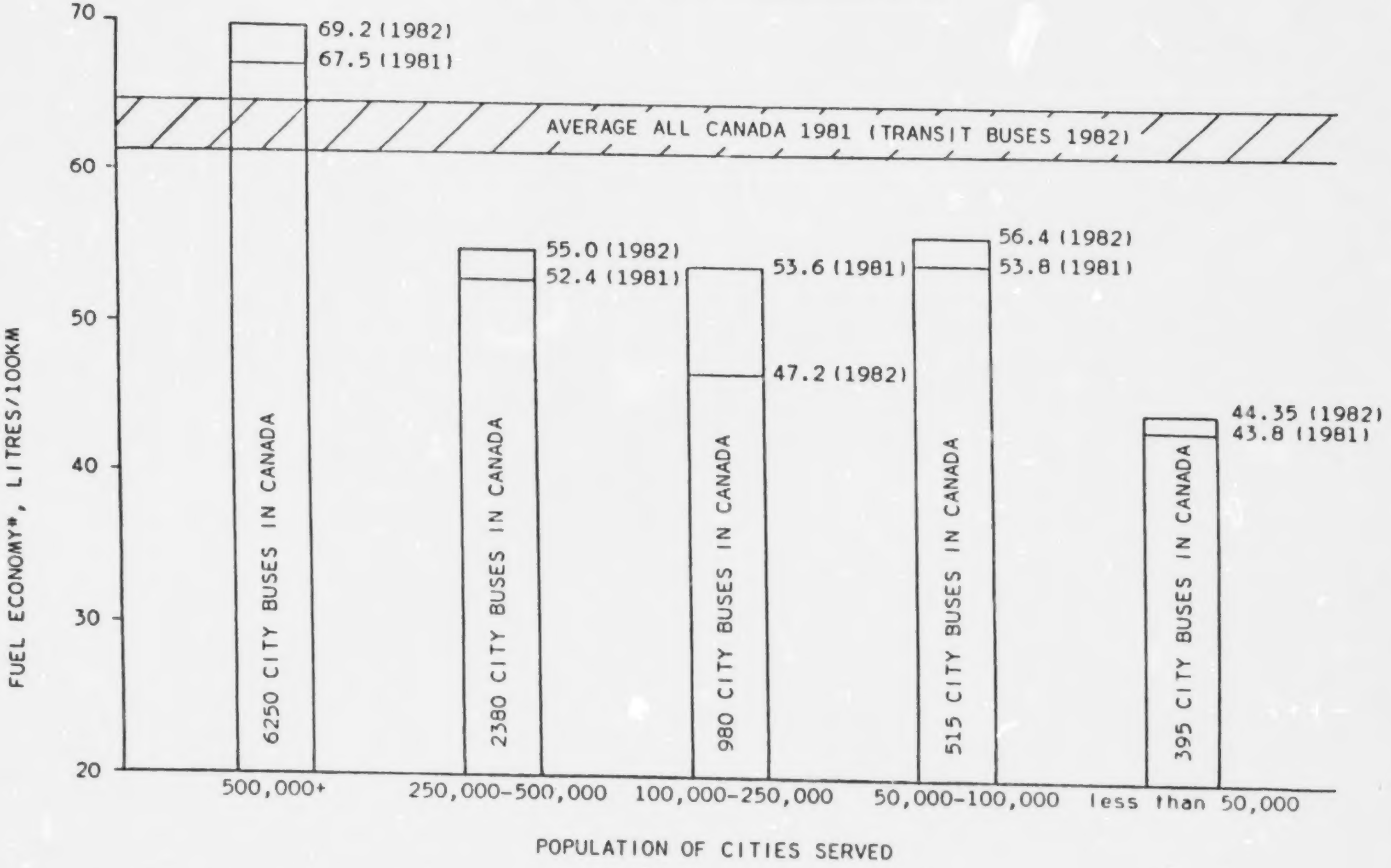
The principal objective of the demonstration at OC Transpo is to gather information on the life-cycle and annual costs of operating propane buses and to compare these costs with those from the current diesel fleet and a higher fuel efficiency (4-stroke) diesel-engined bus.

Our current view of the comparative life-cycle costs of diesel, propane and liquid natural gas-fuelled buses is given in Exhibit 10. The OC Transpo propane costs for the demonstration period are in the 20¢/litre area and expected annual fuel savings per bus under present Ontario tax conditions are about $3,000. For new buses savings in sales tax are also available. The various cases with and without federal and Ontario tax incentives for propane use are summarized in Exhibit 11. Our analysis shows that at the 20¢/litre level for propane and 41¢/litre level for diesel the conversion to propane produces cost savings, but these are dependent upon continued waiver of at least a portion of the road fuel tax on propane. However, only a modest increase in the price of diesel fuel will result in a break-even between propane and diesel, if both are taxed by the province at the diesel or gasoline rate.

Acceptance of propane as a city bus fuel is heavily dependent on the conversion economics and public acceptance of the fuel. The factors critical to the conversion economics are illustrated in Exhibit 12. Only the demonstration of the fleet in revenue service over an extended period will determine the public and bus property response to the propane bus system.

Exhibit 1

FUEL ECONOMY OF CANADA'S CITY BUSES



Data from 1983 report by Canadian Urban Transit Assn., "Operating Characteristics of Member Systems," (1981-1982)

*1982: Total diesel 331.83 million litres; total gasoline 3.735 million litres; in 10,560 active buses.

1981: Total diesel 328.3 million litres; total gasoline 2.82 million litres; in 10,394 active buses.

Exhibit 2

BUS DIESEL FUEL PROBLEMS IN SUMMARY

SUPPLY/DEMAND	CRUDE OIL ISSUES:	- INSUFFICIENT DOMESTIC PRODUCTION
		- UNRELIABLE IMPORTS
	REFINERY ISSUES:	- LIMITED DIESEL PRODUCTION FROM EACH BBL CRUDE OIL
		- DIESEL DEMAND OUTSTRIPS REFINERY CAPACITY
		- SLOW GASOLINE GROWTH AFFECTS DIESEL PRODUCTION
	MARKET ISSUES:	- FAST GROWTH OF DIESEL AND AIRCRAFT KEROSENE USE
QUALITY	CRUDE OIL ISSUES:	- DETERIORATION OF CRUDE QUALITY HAS HEAVY IMPACT ON DIESEL
		- LIMITED #1 QUALITY FUEL AVAILABLE
		- DIESEL SUPPLIES STRETCHED BY QUALITY REDUCTION
POLLUTION CONTROL	FUEL ISSUES:	- INCREASES COMMERCIAL DEMAND FOR DIESEL
		- INCREASES DEMAND FOR #1 DIESEL
	ENGINE ISSUES:	- HIGH COST FOR NOx AND PARTICULATE CONTROL
		- INCREASE IN FUEL CONSUMPTION LIKELY
		- INCREASES ENGINE COMPLEXITY AND SERVICE
		- POOR PROSPECTS FOR 2-STROKE ENGINE
		- NOISE LEGISLATION IS NEXT ON AGENDA
FUEL PRICE		- TEN FOLD INCREASE 1973 TO 1984
		- FUTURE INCREASES HIGHER THAN INFLATION

Exhibit 3

FUTURE OUTCOME FOR CITY BUS PROPERTIES

INCREASED COMPETITION FOR #1 FUEL
WINTER SUPPLY UNCERTAINTIES
MORE COMPLEX ENGINES (POLLUTION CONTROLS)
POLLUTION AND NOISE ABATEMENT MEASUREMENTS REQUIRED

→

HIGHER COST FUEL
HIGHER COST BUSES
HIGHER MAINTENANCE COSTS

↙

NEED FOR HIGH FUEL ECONOMY LOW POLLUTION ENGINES

+

OPPORTUNITY FOR ALTERNATIVE FUELS

Exhibit 4

THE OIL SUPPLY/DEMAND

	1984	1990	1995	2000
DIESEL DEMAND				
m3x1000/DAY	39	47	50	53
CANADA'S IMPORT REQUIREMENT				
MINIMUM m3x1000/DAY	35	26	29	32
COST OF IMPORTS				
MILLIONS $'s (1984)/DAY*	8.1	5.17	6.1	9.5
ANNUAL OIL IMPORT BILL				
BILLIONS $'s (1984)/YEAR	3.0	2.1	2.8	3.5
DIESEL % TRANSPORT FUEL	16	-	-	24-26%

* OIL PRICE FORECASTS (1984 DOLLARS)

1984: $231.40/m3 CIF
1990: 219.33
2000: 297.70

Exhibit 5

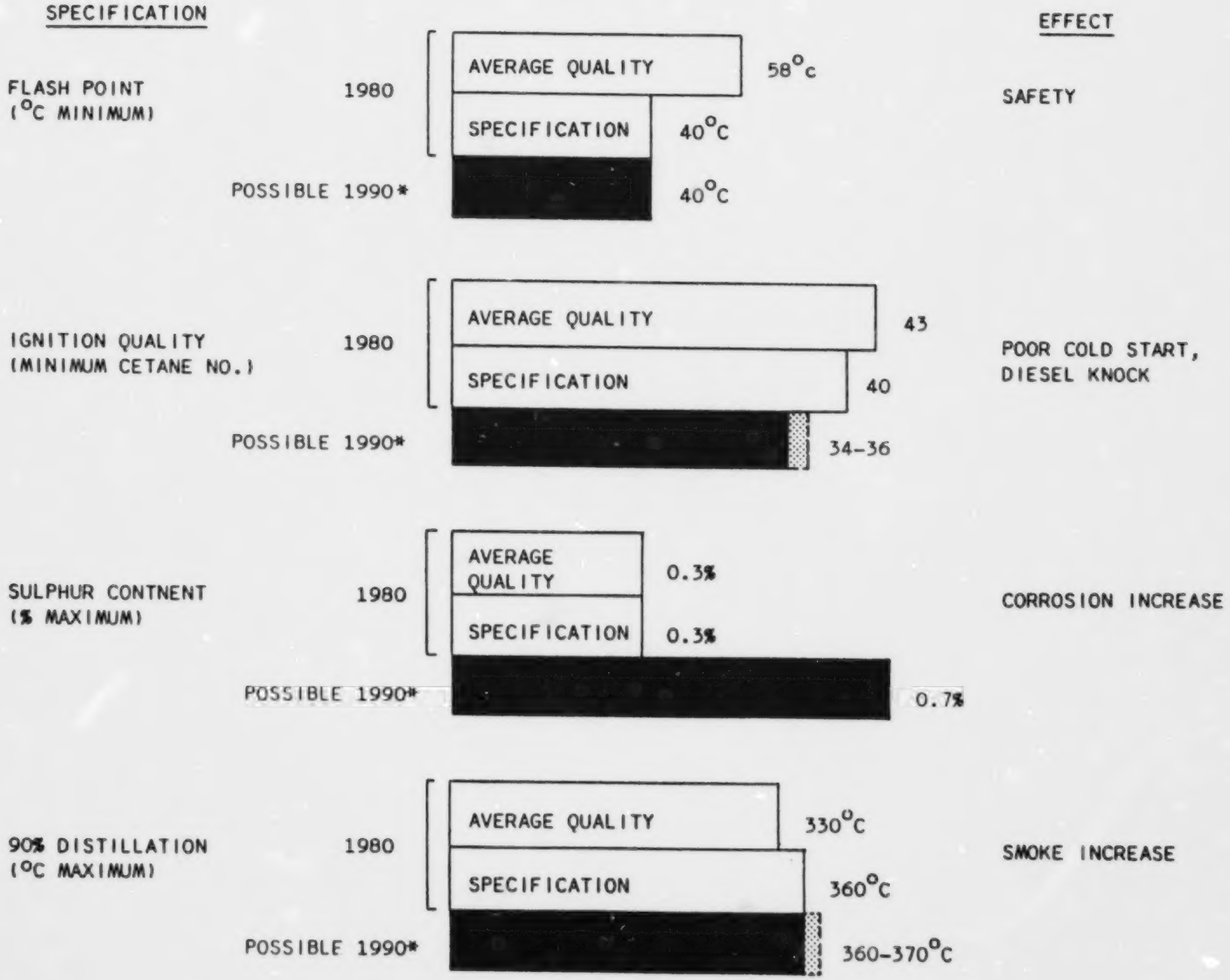
THE REFINERS' PROBLEMS REGARDING DIESEL FUEL

(1000 m3xday)

		1984	2000	CHANGE
1.	DEMAND	39	53	+36%
2.	GASOLINE/DISTILLATE RATIO	1.2	1.01	-12%
3.	DIESEL QUALITY: CETANE # MINIMUM	40	36-37	-10%
4.	COST OF MANUFACTURE (1984 DOLLARS) (28% IS OIL INCREASE)	INCREASES		+35%

Exhibit

DIESEL FUEL SPECIFICATIONS AND 1980 AVERAGE QUALITY



NOTE: * POSSIBLE 1990 = FUEL GRADE UNDER TEST BY CGSB TO SET 1990 STANDARDS.

CURRENT AND TENTATIVE SPECIFICATIONS FROM CSGB. 1980 QUALITY DATA FROM GULF OIL.

Exhibit 7

RATIONALE FOR ALTERNATIVE FUELS

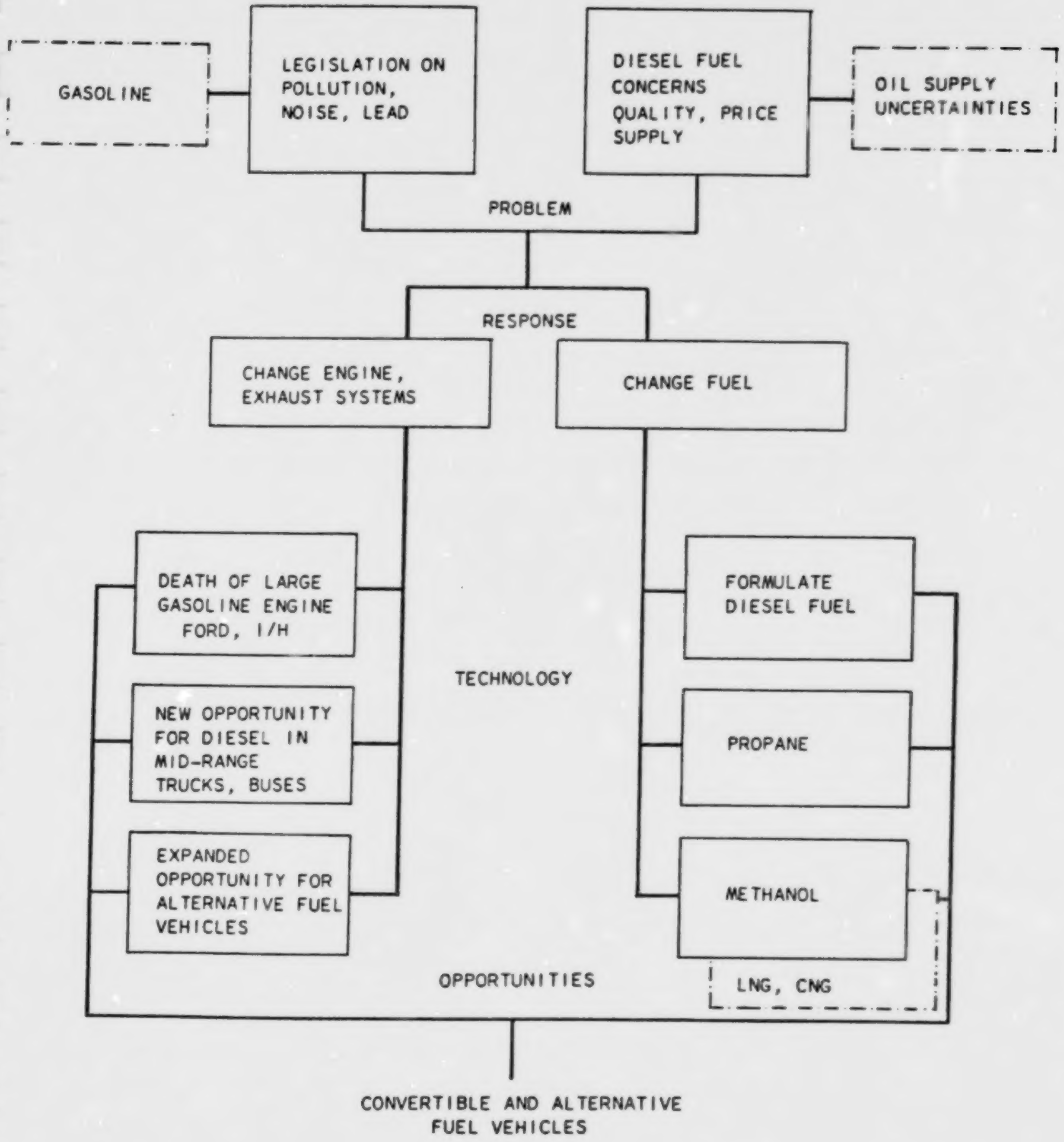

GASOLINE
LEGISLATION ON POLLUTION, NOISE, LEAD
DIESEL FUEL CONCERNS QUALITY, PRICE SUPPLY
OIL SUPPLY UNCERTAINTIES
PROBLEM
RESPONSE
CHANGE ENGINE, EXHAUST SYSTEMS
CHANGE FUEL
DEATH OF LARGE GASOLINE ENGINE FORD, I/H
NEW OPPORTUNITY FOR DIESEL IN MID-RANGE TRUCKS, BUSES
EXPANDED OPPORTUNITY FOR ALTERNATIVE FUEL VEHICLES
TECHNOLOGY
FORMULATE DIESEL FUEL
PROPANE
METHANOL
LNG, CNG
OPPORTUNITIES
CONVERTIBLE AND ALTERNATIVE FUEL VEHICLES

Exhibit 8

OIL AND PROPANE SUPPLY/DEMAND

(all in 1000 m3/day)

	1984	1990	1995	2000
OIL IMPORTS NEEDED	35	26	29	32
PROPANE SURPLUS TO CANADA'S NEEDS	7.5	6.3	5.4	4.3
DIESEL FUEL EQUIVALENT OF CANADA'S PROPANE SUPPLY	11.7	15.9	13.8	11.6
DIESEL FUEL EQUIVALENT OF PROPANE SURPLUS	4.7	3.9	3.4	2.7
TOTAL DIESEL DEMAND	39	47	50	53
CITY BUS DEMAND FOR DIESEL	0.91	0.92	0.94	0.94

CONCLUSIONS:
1. PLENTY OF SURPLUS PROPANE FOR BUS & TRUCK CONVERSIONS
2. GAS EVEN MORE SO

Exhibit 9

PROPANE CONVERSION BENEFITS

- AUGMENTATION OF DIESEL SUPPLY BY SURPLUS PRODUCT
- COST OF PROPANE CAN BE LOWER THAN DIESEL WITH TAX INCENTIVES
- IMPROVED QUALITY OF RIDE - NOISE
  VIBRATION
  PULL AWAY FROM STOPS
- LOWER LEVELS OF POLLUTION
  AND POLLUTION CONTROL TECHNOLOGY IS SIMPLE

Exhibit 10

LIFE-CYCLE COSTS PROPANE, DIESEL, LNG

ONTARIO EXAMPLE

	DIESEL	PROPANE	LNG
FUEL COST AT PUMP ¢/LITRE*	41.64	22.06	19.65
BUS CONVERSION PREMIUM $	BASE	2,900	9,800
AFTER TAX CONVERSION COST (SAVING)	BASE	(9,050)	2,750
ANNUAL FUEL COST $	13,526	12,194	11,980
VARIABLE COST/ANNUM	68,421	67,089	66,875
FIXED COST/ANNUM	27,795	27,141	27,633
TOTAL COST/ANNUM	96,216	94,230	94,508
ANNUAL SAVINGS OVER DIESEL	-	1,986	1,708
SAVINGS WITH PROPANE AT 20¢/litre	-	3,092	-

* DIESEL TAXED, PROPANE & LNG UNTAXED, BUT COSTS OF FUELLING FACILITY INCLUDED

[illegible]

CHANGES IN ANNUAL COST WITH PROPANE AND DIESEL BUSES

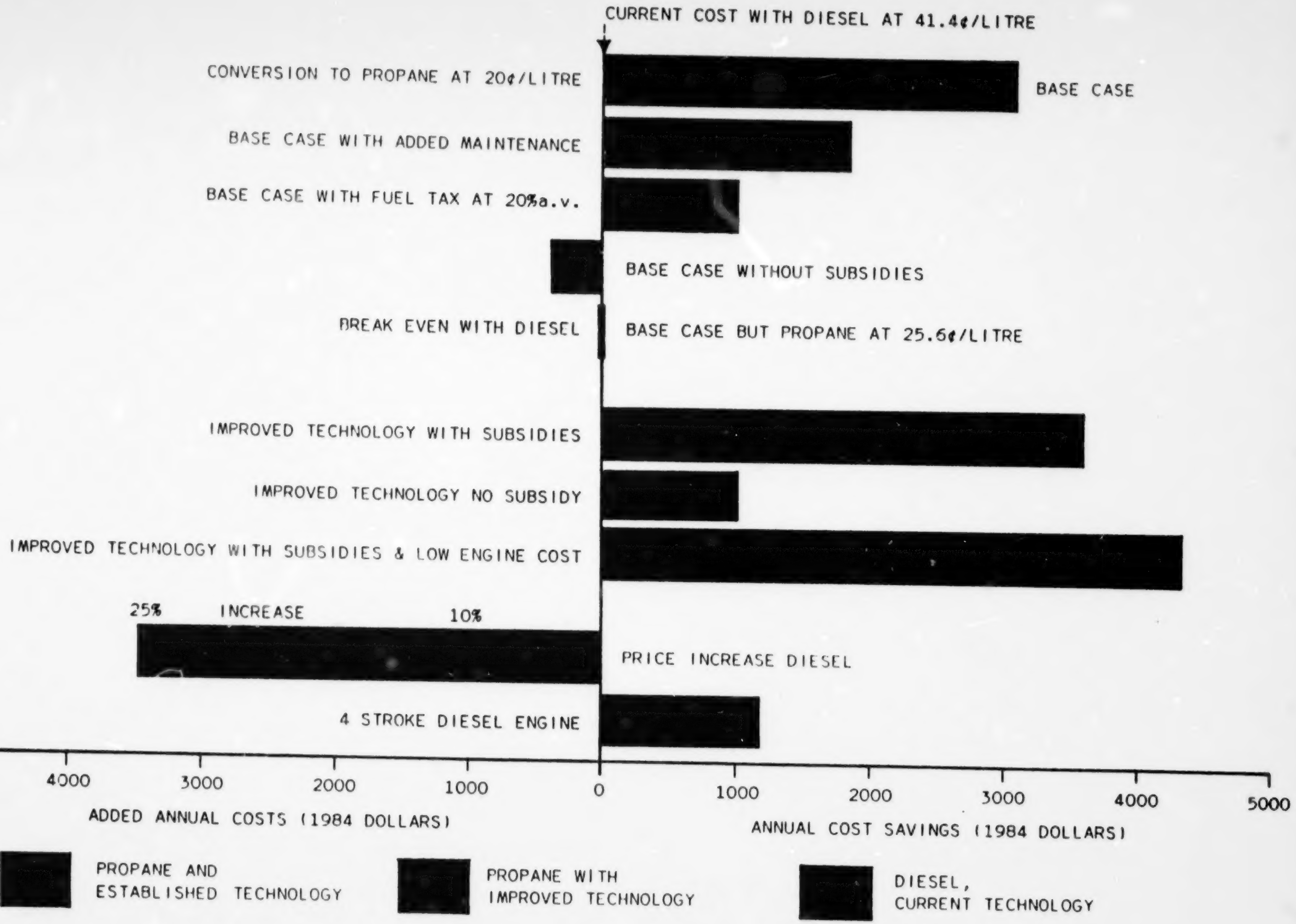


Exhibit 12

CRITICAL FACTORS FOR CONVERSION ECONOMICS

1. CONTINUED REMISSION OF SALES TAX ON VEHICLE
2. CONTINUED REMISSION OF FUEL TAX
3. NO LARGE INCREASE IN MAINTENANCE COSTS FOR PROPANE
4. CONTINUED COMPETITIVE PRICING OF PROPANE
5. IMPROVEMENTS IN FUEL CONSUMPTION TOWARDS THEORETICAL PROPANE TO DIESEL VOLUME 1:1.5
6. REDUCED COST OF PROPANE ENGINE AND PROPANE TANKS
7. LOW FUEL STORAGE AND REFUELLING COSTS
8. RETENTION OF RIDERSHIP THROUGH RIDE QUALITY IMPROVEMENT WITH PROPANE

PAPER #3 - "A PROGRESS REPORT ON THE OC TRANSPO PROPANE DEMONSTRATION"

by W.D. Jenkins, Propane Demonstration Project Manager, OC Transpo

1. Introduction

The project has three phases:

1. Initial engine installation.
2. Prototype engine testing-specification compliance by engine supplier and GO/NO-GO acceptance.
3. Operation in revenue service.

Phases 1 and 2 have been successfully completed. Phase 3 has begun.

2. Engine Installation

The Dereco (FIAT Iveco) engine selected for the demonstration is an in-line 6 cylinder, 4-stroke spark-ignition engine installed in the bus at 15° to the vertical in the compact engine compartment of selected 1979 versions of the "New Look" GM bus. The new engine was designed to be coupled to the standard V730 transmission of the "New Look" bus via an adapter. This marriage resulted in some changes being required in the engine cradle, exhaust system, drive shaft and the general service lines cooling system. One major problem for the supplier was to convert their diesel engine to one which rotates in the same unique sense as the GM-6V71 bus engine. The outcome of our work is that the installation of the propane engine will be no more complex than that of the conventional diesel engine.

3. Fuel Tank

The target for the fuel tank assembly was to obtain a range in the converted bus equivalent to that of the diesel bus equipped with a 900 litre diesel tank, but spatial restrictions in the 1979 bus chosen allow only the installation of a 800 litre propane tank, which is not expected to cause problems since this assembly will provide a usable bus range of about 700 kilometres.

As shown in Exhibit 1, the design of the propane tanks consists of 4 vessels manifolded into one single tank. All gauges and main valves are located at one position for easy access and rapid refuelling. The tank was designed and built by Westeel Corporation for maximum safety with additional undertank protection for unusual road hazards such as manhole covers. All regulations governing propane installations in vehicles have been met.

In the future we will investigate improved tank designs to permit filling from either side of the bus and to provide automatic monitoring and cut-off of the fuel at the 80% fill level.

4. The Fuelling Facility

Research has shown that major problems occur during refuelling. For example, driving away while the bus is still connected to the supply, and overfilling of the fuel tank beyond the 80% level. In cold weather this causes a safety hazard when the fuel is heated by inside storage of the bus when the fuel may be vented through the safety valve.

The fuelling facility is designed with a quick release system in the fuel hose to avoid damage and fuel loss if the bus is driven away while still coupled to the fuelling island: fuelling is to be achieved by use of a "dead-man's handle".

5. Testing of the Prototype Bus

The specifications set the propane engine manufacturer required that the road performance of the retrofitted bus would match that of a standard bus chosen from the OC Transpo fleet equipped with the 6V71 diesel engine and C55 injectors. Exhibit 2 shows that to all intents and purposes the acceleration performance of the propane and diesel buses is identical. The propane bus shows a higher torque value at low rpm (up to 25 kilometers per hour vehicle speed) which has resulted in positive driver response and is particularly beneficial for operations in a downtown area.

Engine dynamometer testing by the engine supplier has shown good repeatability in performance for the series production engines, and we look foward to demonstrating this in our 15 bus fleet.

The prototype bus and a diesel-engined bus of similar age were tested over two typical routes in the OC Transpo system.

On route #1, a downtown route with many stops, and on a suburban route #9, the speed made good with the propane bus was slightly better than that of the corresponding diesel engine.

Speed made good	Diesel bus	Propane bus
Downtown Route #1	14.92 KPM	15.40 KPM
Suburban Route #99	33.95 KPM	34.87 KPM

The route times and details of the route tests with the prototype propane bus are summarized in Exhibit 3.

The economics of the propane bus require that it should consume not more than 1.8 volumes of propane for each one volume of diesel fuel displaced. Fuel consumption tests were conducted with the matched prototype propane bus and the selected diesel bus at a test track in the Ottawa region, kindly made available to us by the department of National Defence.

The tests were conducted using an Advanced Design Bus test cycle which simulates a mix of city, arterial and commuter service. The ADB cycle was modified to suit the 1.75 mile test circuit available. The tests were repeated until 5 sets of results were obtained which varied by less than 2.5% from the mean.

The fuel economy test results summarized in Exhibit 4 show that the volumetric fuel consumption of the propane-engined bus was 1.7 times that of the matched diesel-engined bus and the less than 1.8 ratio of fuel consumption required had been met. It is anticipated that further refinement of the propane engine and settings can reduce the volumetric propane to diesel fuel ratio to the 1.6:1 level but even at the level currently demonstrated the results are encouraging.

6. Noise Testing

The propane bus is demonstrably quieter than the diesel bus to the extent that conversion is possible within the bus and the low level noises from rattling windows become obvious, whereas in the diesel bus these low level noises are normally masked by the diesel engine noise. In the propane bus steps must therefore be taken to reduce the low level noise. The results of the preliminary interior noise tests in the propane and diesel buses are given in Exhibits 5 and 6 which relate to tests under stationary and constant bus speed conditions. "Drive by" noise testing and vibration tests are incomplete and will be reported when completed.

7. Interim Conclusions

Initial driver response to the propane bus has been remarkably positive. No public response has been obtained to the propane bus in service, but we interpret this also as a positive sign.

In the coming months we will pay particular attention to the installation in the garage of safety features specifically designed for propane and to making the operation of the propane fleet routine. We are pleased with the quality of the engines and components we have received and with the enthusiastic and professional assistance we have received from the participants in the demonstration, our drivers and mechanics, our suppliers and advisers.

We intend to produce a final report on the demonstration which will quantify the viability of propane as a transit fuel of the future - at least within the OC Transpo system.

Exhibit 1

THE BUS FUEL TANK SYSTEM

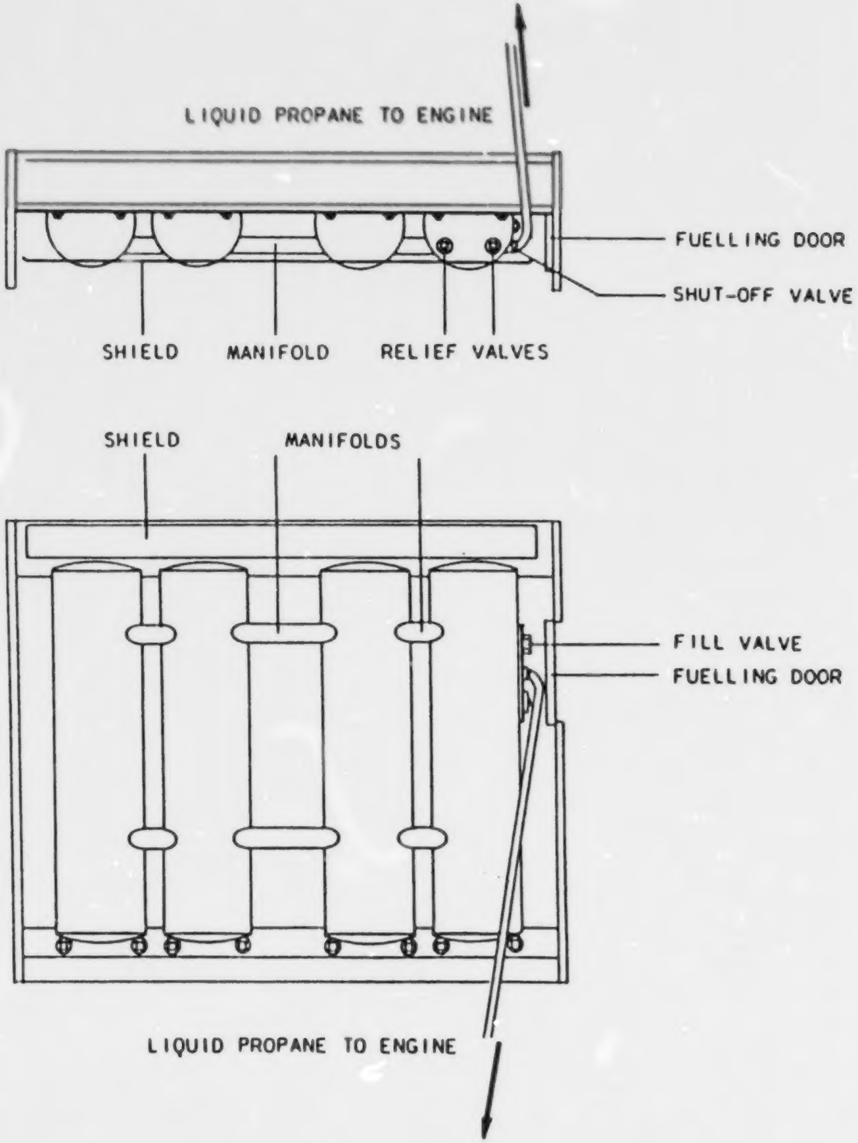

LIQUID PROPANE TO ENGINE
FUELLING DOOR
SHUT-OFF VALVE
SHIELD
MANIFOLD
RELIEF VALVES
SHIELD
MANIFOLDS
FILL VALVE
FUELLING DOOR
LIQUID PROPANE TO ENGINE

Exhibit 2

COMPARISON OF ACCELERATION OF PROPANE AND DIESEL BUS

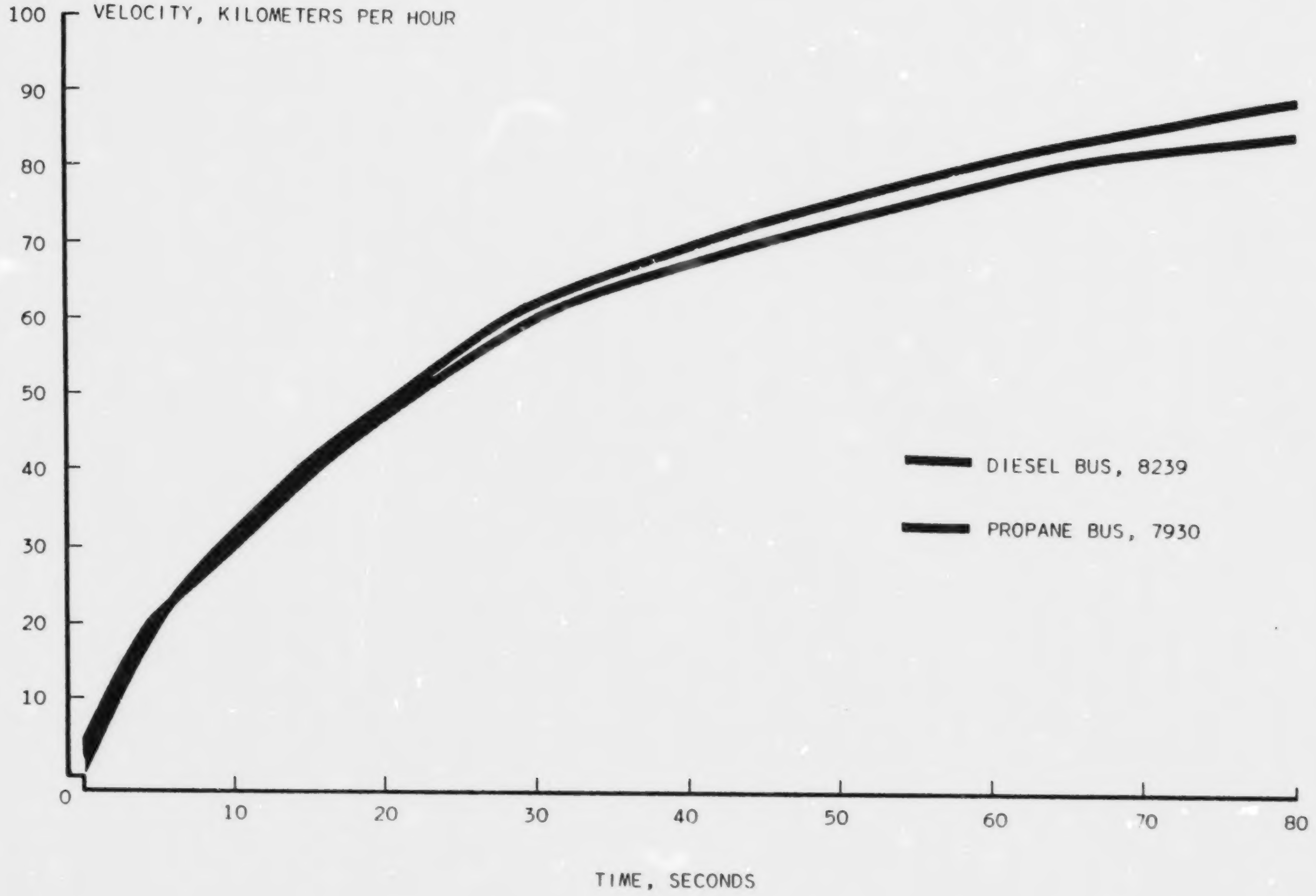


Exhibit 3

ROAD TEST: PROPANE AND DIESEL BUSES

	CITY ROUTE #1		SUBURBAN ROUTE #99	
	DIESEL	PROPANE	DIESEL	PROPANE
OFFICIAL STOPS (10 SEC.)				
NUMBER	80	80	31	31
TIME	13 MIN. 20 SEC.	13 MIN. 20 SEC.	5 MIN. 10 SEC.	5 MIN. 10 SEC.
ADDITIONAL STOPS				
NUMBER	29	27	25	24
TIME	7 MIN. 8 SEC.	6 MIN. 35 SEC.	5 MIN. 3 SEC.	4 MIN. 50 SEC.
TOTAL TIME	62 MIN. 20 SEC.	61 MIN. 57 SEC.	51 MIN. 36 SEC.	51 MIN. 17 SEC.
MEASURED LENGTH OF ROUTE	15.5 KM	15.9 KM	29.2 KM	29.8 KM
AVERAGE SPEED	22.21 KM/HR	23.04 KM/HR	42.3 KM/HR	43.3 KM/HR

Exhibit 4

FUEL CONSUMPTION COMPARISON
PROPANE AND DIESEL BUS (MARCH 1984)

7 LAPS OF 1.747 MILES: TOTAL 12.23 MILES IN ADB-CYCLE TEST

	DIESEL	PROPANE
CONSUMPTION, POUNDS	18.6-19.6	20.0-20.6
AVERAGE CONSUMPTION, POUNDS	19.08	20.22
AVERAGE CONSUMPTION, IMP. GALS.	3.965	2.33
FUEL ECONOMY, MPG	5.256	3.965
LITRES/100 km.	53.65	91.4
RATIO PROPANE TO DIESEL VOLUME		1.7
GO/NO-GO TEST REQUIREMENT		NOT GREATER THAN 1.8

Exhibit 5

INTERIOR NOISE MEASUREMENTS - STATIONARY PROPANE AND DIESEL BUS

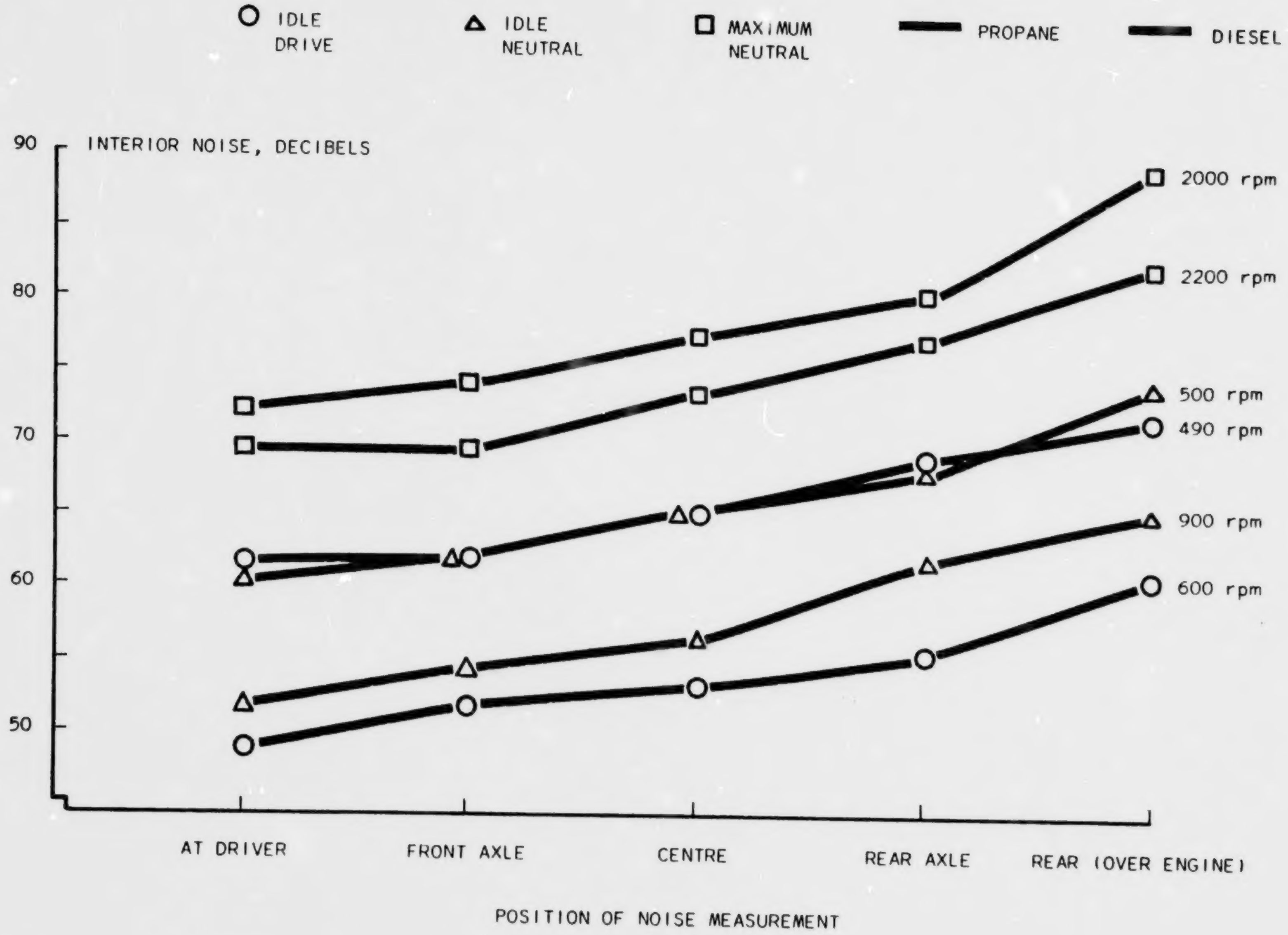
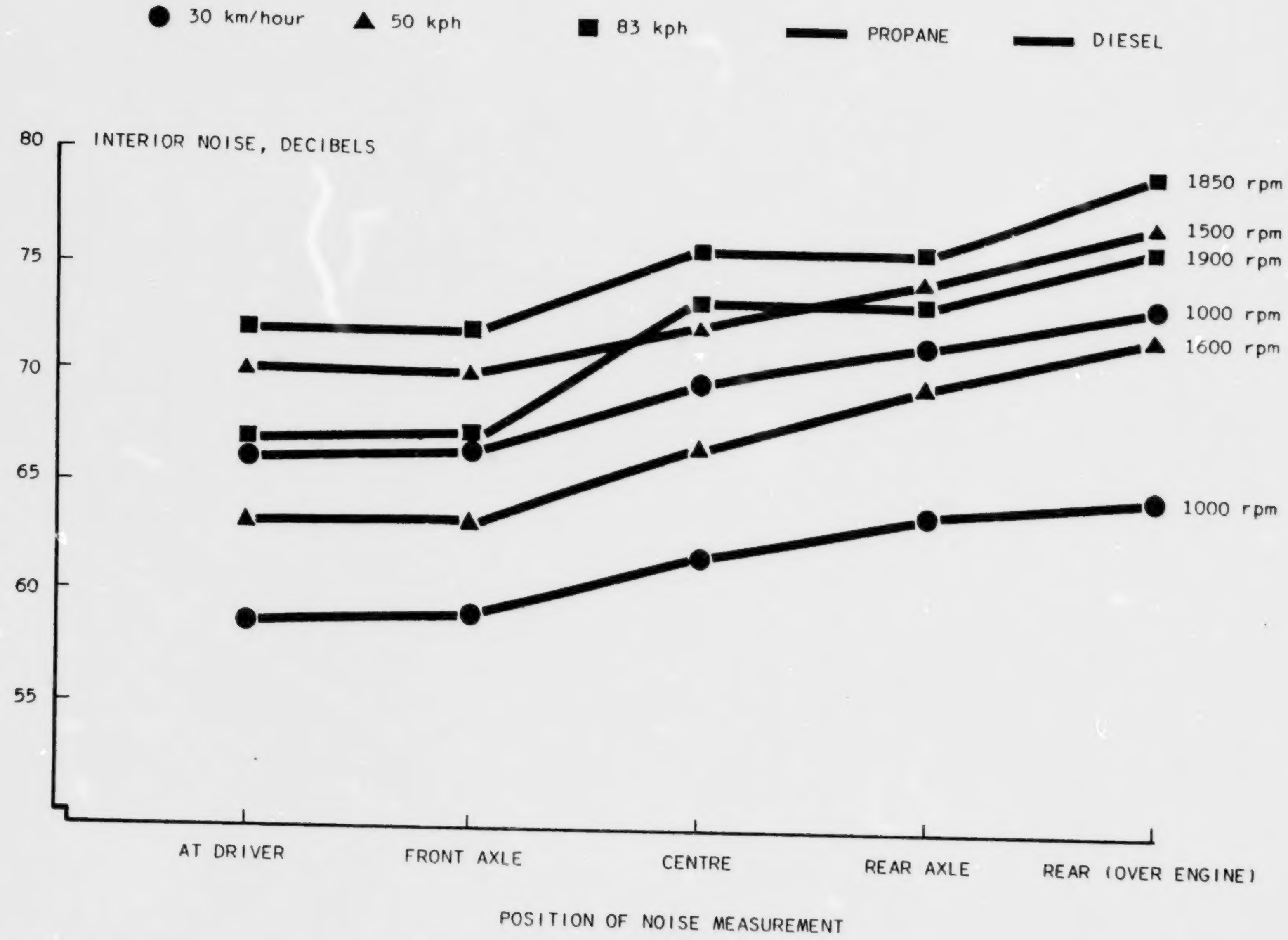


Exhibit 6

INTERIOR NOISE MEASUREMENTS - CONSTANT SPEED PROPANE AND DIESEL BUS



DRAFT

TECHNICAL REPORT #6 22 February 1985

PROPANE DEMONSTRATION DATA SYSTEM (PDDS)

1. PURPOSE

The revenue service operation of the 15 propane buses and one diesel is scheduled for the 2-year period starting about 1 April 1985. This report reviews the data acquisition analysis and reporting components of the demonstration - the intent being to obtain comments and incorporate added requirements early in the revenue service operation. The data system proposed incorporates the level of data reporting required to support the information and technology transfer requirements of the ENERDEMO program of EMR, in addition to that required by the Ontario ministries.

2. PRINCIPAL OBJECTIVES OF THE DATA SYSTEM

2.1. Generation of an Equipment Data Base

The assembly and storage of data throughout the demonstration period on the operation, performance, safety, operating and capital costs of the equipment and personnel involved in the demonstration including:

a. the set of 15 propane buses
b. one 4-cycle diesel-engined bus
c. other engines and components purchased for the demonstration (spare engines, new design fuel tanks, special test equipment)
d. the bulk fuel storage facility and pipeline
e. the refuelling facility
f. in-garage equipment related to the retrofitting, testing, maintenance and operations of the demonstration fleet
g. the conventional bus fleet, fuel and other equipment to provide a

means for comparing data from the conventional 2-cycle bus fleet and the test fleet.

2.2 Generation of a Personnel and Rider Database

The maintenance of lists and other records related to the human resources employed and passengers carried in the demonstration period:

a. records of propane qualified personnel, training and certification status
b. records of enquiries and responses to the propane service from the public, OC Transpo employees and other fleet operators
c. lists of contractors, suppliers; lists of correspondence with them and their current catalogues.

2.3 Analysis

Conversion of raw data from the demonstration into data assembled in appropriate form (tables, graphs, edited text and other records) to facilitate statistical analysis and rapid assembly of status and current reports on the operations, safety and cost of the propane system and attitudes to the system which can be related to the conventional diesel system.

Statistical procedures will be utilized in the analyses where appropriate to improve the quantification and confidence level of the data reports.

2.4 Reports

Generation of information on the demonstration in formats suited to the recipients of the reports and publications to be issued including the following reports:

a. technical, economic and final
b. project progress
c. special topics, such as safety incidents and background
d. driver and public response
e. publications in technical journals and magazines
f. publicity
g. technology transfers and seminars
h. schedules and budgets/expenditures.

3. DATA COLLECTION AND PROCESSING

3.1 Data Collection Instruments

The demonstration will generate physical records in the form of daily, weekly, monthly and other entries into a log book maintained for each vehicle in the test. Other log books will be maintained for the major equipment items: the fuel storage facility, the fuelling station, the propane bus storage and maintenance section of the St. Laurent garage, the safety instrumentation and equipment, and the new test equipment.

The log book will be checked weekly to ensure compliance. Wherever possible the data logged will be recorded on an itemized preset check-list with minimum reliance on written commentary. The weekly check for compliance will be made at the time data is transferred to a computer-based data storage system. The logged data will therefore be stored in physical and computer files.

In addition to data captured in the log books, other sources of data on the demonstration include various lists and reports special to the demonstration as described below, and data on the demonstration buses and all other buses (already generated by the existing OC Transpo system). This includes the summary records on maintenance, operations, costs and labour, now generated by the existing computerized system.

Additional items will be added to the current OC Transpo reporting system to capture data specific to the demonstration fleet and transfer it on a weekly basis to the propane project data system (PPDS).

The PPDS will also maintain records of special investigations, such as the driver/rider survey data, safety inspections, training data and all analyses and reports issued during the demonstration period.

The records now seen to be required are presented below. Others will need to be added as the demonstration proceeds.

4. RECORDS IN THE PROPANE PROJECT DATA SYSTEM (PPDS)

4.1 Vehicle Records

Each vehicle data entry will record the bus #, date and data origination.

4.1.1 Initial Inspection Records

These contain:

a. specifications on vehicle components unique to propane and the 4-cycle diesel
b. manufacturers' reports/inspections, run-in data (engines, fuel tanks, lines, controls)
c. OC Transpo inspection/acceptance on components
d. bus conversion certification and inspection report (check list) includes safety inspection
e. post-conversion performance test (dynamometer test, optimization for service/fuel economy check-list)
f. other bus characterization data (ignition settings, electrical system, cooling system, hubometer reading, tires (tread depth), battery fluid (specific gravity), fuel level, lubricating oil

level, antifreeze incorporated, front/rear axle inspection, spark plug gap measurement and visual inspection, checks of other components noted in present inspection records

g. road test.

4.1.2 Daily Vehicle Inspections

In addition to current daily "count-down" items will include:

a. volume of propane (and diesel for 4-cycle engined bus), lubricant, antifreeze solution added
b. hubometer reading
c. assigned daily route (predetermined daily kilometrage).

Daily records will also be maintained on road/weather conditions and ambient temperature to facilitate analysis.

4.1.3 Monthly Vehicle Inspections

At 4 week intervals:

a. demonstration vehicle monthly safety inspection - tanks, lines, valves, other items on check list. Details of items to be recorded are given in the report "A Safety Manual for Propane Bus Systems"
b. tire wear (tread depth)
c. all items now recorded for monthly inspection in conventional buses will be included
d. where maintenance is required, a descriptive copy of the work order raised will be maintained.

4.1.4 Vehicle Maintenance Records

a. a copy of the completed work order for maintenance/repair will be retained: this will give more detail than now recorded on hardware problems and solutions made

b. a report of the visible inspections made before and after maintenance/repair, plug gap measurement or replacement, compression, pressure regulator, tank inspection, fuel line inspection, dynamometer test

c. report on special safety check after repair to propane components.

4.1.5 Special Propane Vehicle 8 Week Interval Inspections

Not now performed on diesel buses:

a. engine performance tests - dynamometer, check engine settings

b. oil sample - analysis required

c. battery fluid - specific gravity

d. check shut-off valve.

4.1.6 Year-End Inspection

At mid- point and conclusion of demonstration.

a. repeat of post conversion performance tests and bus characterization (see 4.1 above)

b. year end compilation of data to facilitate final and interim reports

c. special tests, probably include pollution measurement.

4.1.7 Special Tests

Reports on Track Test, noise and vibration and other special tests yet to be defined and raw data are maintained.

4.1.8 Final Inspection

a. repeat of post conversion performance tests and bus characterization

b. tear-down reports - engine, fuel lines, carburetion, vapourizer for deposits, wear, corrosion

c. compilation of data on demonstration vehicles

d. comparable data on conventional diesel fleet to facilitate comparison

4.2 Fuel Storage and Refuelling Facility Records

As with the Vehicle Records, further records will be generated for the fuel/fuelling system at the initial inspection/acceptance stage from daily operations, monthly and annual for interim and final reports as follows.

4.2.1 Initial Facility Inspection

a. records maintained of Bulk Fuel Storage facility specifications, drawings, etc.

b. inspection and provincial certification of the bulk storage facility conducted with representatives of OC Transpo, the Pressure Vessels Inspection Authority (Ministry of Consumer and Commercial Relations, Ontario), the Ottawa Fire Department and Superior Propane. A check list of items inspected and certified is given in "A Safety Manual for Propane Bus Systems" and the "Ontario Propane Storage Handling and Utilization Code".

4.2.2 Refuelling Station

Records will be maintained on the refuelling station and components, and an acceptance inspection report prepared with input from OC Transpo, Superior Propane, the Ontario Ministry of Consumer and

Commercial Relations (Fuels Safety Branch).

A series of tests will be conducted on the fuelling facility and recorded, including the condition and operability of: the dead man's switch; all electrical switches in the system; pumps and valves; fire extinguishers; fencing; communications to/from fuelling station; integrity - leaks, wear of fuel hoses, fuel pistol. The rate of bus refuelling will be checked.

A record will be maintained of training given, fuel and safety procedures posted.

4.2.3 Daily Records

a. propane delivered to site - volume reported
b. fuel loaded into each bus - volume reported - propane and diesel (4-stroke bus), lubricants and antifreeze added
c. notification of major spills, leaks in the fuel storage refuelling operation
d. refuelling system daily safety inspection reported - check list
e. all safety incidents involving fuelling personnel, refuelling facilities, propane delivery trucks
f. records maintained of lubricating oil samples (sent to Imperial Oil for analysis).

4.2.4 Monthly Inspection

a. the bulk storage facility will be inspected monthly and details reported - check list
b. the refuelling centre equipment will be checked and reported - check list
c. monthly summaries will be prepared of fuel consumption, lube oil addition and sample analyses conducted for each bus in the demonstration fleet

d. the propane supplier will provide spot analyses of the propane quality compared to HD-5 quality: sample will also be checked independently from time to time.

4.2.5 Final Inspection Reports

a. one will be based on a final inspection of the facilities and preparation of a report on wear, failures, incidents and material/components consumed or replaced

b. another on fuel use, losses, costs and quality variations in the demonstration program.

4.3 Garage Records

4.3.1 Facilities Reports

Maintain records of all changes made to garage, instrumentation installed, safety equipment (alarms, sensors, fire extinguishers, ventilation system) and where applicable, list of specifications, suppliers' tests, manuals.

4.3.2 Acceptance Test Reports

All acceptance inspections and tests, including safety certification by the province, on propane-related equipment installed in the garage will be recorded.

4.3.3 Daily Reports

Exceptions to standard bus garage practice will be logged. This includes activities specific to propane, incidents in the garage involving propane equipment (collisions, alarms, leaks), propane service equipment failures, equipment replacement, repairs. (Work orders will capture maintenance and repair items).

4.3.4 Monthly Inspection Reports

Check-list used to record inspection of fire and safety equipment, displays, signs within the garage.

4.4 Accounting Records

The existing accounting system will be used to generate special monthly reports on expenditures including:

4.4.1 Capital Expense Report

Monthly records of unexpensed capital goods purchased in period by category:

- vehicle-related equipment (engines, tanks, spares, major components)
- fuel storage facility and refuelling facility investment
- garage test, safety, instrumentation equipment
- special tools, signs, training aids.

4.4.2 Operating Expense Report

Monthly reporting of propane and demonstration diesel bus operating costs but excluding items which are common to the propane fleet and the current fleet (driver costs, tires, and allocated overheads). Fuel, spark plugs, lubricating oil and other consumable propane engine related materials are included.

4.4.3 Maintenance Repair Expense Report

Identifies monthly maintenance/repair expenses particular to the propane fleet (extra engine overhauls and special repairs). Items common to all buses (interior and exterior maintenance) are excluded from the data collection system.

4.4.4 Project Administration

The costs of administering the demonstration, training and consultant fees are recorded monthly.

4.4.5 Budget Control

An analysis will be prepared monthly of expense versus budget and exceptional items which may lead to budget/schedule revisions.

4.5 Other Records Maintained

These include:

4.5.1 Staff Records

Include a list of S6A, S6B certified staff, trained fuellers, staff training courses (training material lists and examples on file). Driver responses, complaints and other issues related to personnel will be recorded.

4.5.2 Ridership Records

Lists will be maintained to identify locations of rider responses and correspondence. Copies of surveys will be held in files.

4.5.3 Publication Records (Information Transfer)

Lists are to be maintained of location, dates, and titles of prepared papers, seminars, publicity and project-related correspondence. Copies of all technical reports generated in the program will be maintained on file.

4.5.4 Safety Records

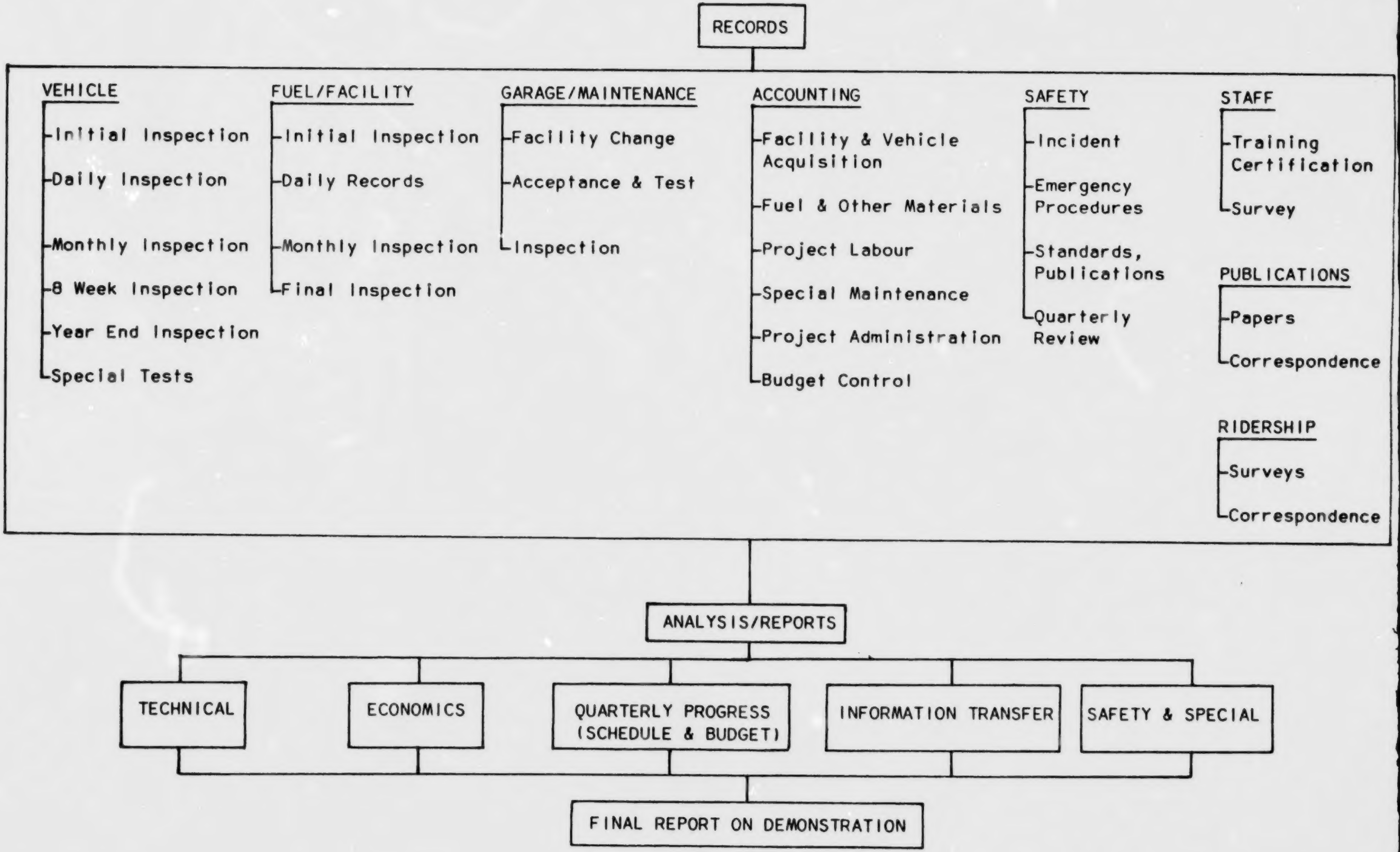
A summary of the safety aspects of the demonstration will be maintained in a dedicated set of records for rapid access. The safety records will include inspection/certification schedules, emergency fire and safety procedures, incident reports, and statistics. A file of standards and safety-relevant publications will be maintained for reference purposes.

A Quarterly review report on safety will be issued.

5. REPORTS

The records will be used to prepare analyses of data, reports and publications as shown in the Exhibit "Data Sources and Report Summary" (technical, economic, quarterly progress, safety, special, publications (and information transfer and the final reports).

EXHIBIT: DATA SOURCES AND REPORT SUMMARY (PDDS)


RECORDS
VEHICLE
Initial Inspection
Daily Inspection
Monthly Inspection
8 Week Inspection
Year End Inspection
Special Tests
FUEL/FACILITY
Initial Inspection
Daily Records
Monthly Inspection
Final Inspection
GARAGE/MAINTENANCE
Facility Change
Acceptance & Test
Inspection
ACCOUNTING
Facility & Vehicle Acquisition
Fuel & Other Materials
Project Labour
Special Maintenance
Project Administration
Budget Control
SAFETY
Incident
Emergency Procedures
Standards, Publications
Quarterly Review
STAFF
Training Certification
Survey
PUBLICATIONS
Papers
Correspondence
RIDERSHIP
Surveys
Correspondence
ANALYSIS/REPORTS
TECHNICAL
ECONOMICS
QUARTERLY PROGRESS (SCHEDULE & BUDGET)
INFORMATION TRANSFER
SAFETY & SPECIAL
FINAL REPORT ON DEMONSTRATION

APPENDIX C

UTDC TEST REPORT ON DDA 6V-71 DIESEL ENGINE

CONTENTS

SECTION	TITLE	PAGE NO.
	TITLE PAGE	i
	REVISIONS	ii
	SUMMARY	iii
	CONTENTS	iv
1.0	INTRODUCTION	1
2.0	TEST DEFINITION	2
2.1	Test Parameters	2
2.2	Vehicle Data	2
2.3	Accessory Loads	3
2.4	Fuel	3
3.0	TEST FACILITY	5
3.1	Facility Layout	5
3.2	Test Rig Structure	5
3.3	Dynamometer	7
3.4	Data Acquisition and Control System	7
3.5	Fuel System	12
3.6	Exhaust System	14
4.0	ENGINE MAP TESTS	15
4.1	Procedure	15
4.2	Test Results	18
4.3	Comparison to Manufacturers Data	

SUMMARY

The baseline tests carried out on the DDA 6V-71 Diesel engine are described and the results summarized in this test report. Tests carried out consisted of an Engine Map and Simulated driving cycles consisting of all or part of the Advanced Design Bus (ADB) routes. The tests were carried out on the computer controlled dynamometer at the UTDC Kingston test site.

The engine map results compare well with the manufacturers data for the engine, and at the minimum specific fuel consumption point agree within 3%. The ADB route results show a scatter of ±2.5% at vehicle empty, ±3% at medium payload and ±2.5% at maximum vehicle weight. The ADB route results agree in magnitude and trend with road test results.

SECTION		TITLE	PAGE NO.
5.0		ROUTE TESTS	23
	5.1	General	23
	5.2	Procedure	23
	5.3	Test Results	25
	5.4	Comparison to Road Tests	32
	5.5	Partial Route Tests	32
	5.6	Exhaust Manifold Temperature Tests	35
6.0		CONCLUSIONS	38
		APPENDIX A - TEST DETAILS	
		APPENDIX B - ENGINE PERFORMANCE MAP RESULTS	

UTDC Research & Development Ltd.

Project	**Title**	**Report No**			
		552-630-012			
		Date	**Issue**	**Page**	
		85.01.27	1	1 of 38	
Engine Test	DDA 6V-71 Test Report	**By** J.H.S.	**Appd**		

1.0 INTRODUCTION

This test report describes tests carried out as part of a project which has the overall objective of determining the difference in fuel consumption between a baseline bus engine, the 2-stroke Detroit Diesel Allison 6V-71N, and two 4-stroke engines one running as a normal diesel, and the other converted to operate on propane by the manufacturer, IVECO. The fuel consumption differences were measured both during steady state conditions (the engine map) and during typical bus driving cycles simulated on the dynamometer.

This project is part of a larger program being conducted by the Ottawa-Carleton Transit Commission (O.C. Transpo) to investigate the economic benefits of partial or complete conversion of their bus fleet (Approximately 800 buses) to propane. Road testing of converted buses has started, and some results are available for comparison to the test cell project.

2.0 TEST DEFINITION

2.1 TEST PARAMETERS

The tests are summarized in Table 1, with the details of the cycles defined in Appendix A.

2.2 VEHICLE DATA

Engine: DDA 6V-71N
C-55 Injectors

Axle: 5.125:1

Transmission: DDA V730

Shift Points	Up (RPM)	Down (RPM)
1 Lock Up	1035-1115	-
1 to 2	1950	360 to 765
2 to 2 Lock-Up	1700-1780	595 to 865
2LU to 3LU	2100-2220	1850 to 2020

Tires: 41.25" Rolling Diameter
12 x 22.5 14 Ply Goodyear

Accessories: Cooling Fan
Alternator
Air Compressor

2.3 ACCESSORY LOADS

For the Engine Map:

No Fan:
Alternator: No Load
Air Compressor: No Load

For All Cycles:

Engine Fan Connected:
- DDA - Continuously Variable
- IVECO Propane - Thermostatic
- IVECO Diesel - Thermostatic

Alternator: 600 w Load

Air Compressor: 16 S.C.F.M. @ 116 psig
(Approximately 25% Rated Flow)

2.4 FUEL

No. 1 Diesel (Gulf 20x)
(See Table 2)

TEST	CYCLE	VEHICLE WEIGHT lb	COMMENT
0	ENGINE MAP	Not Applicable	See Appendix A for Details
A	COMPLETE ADB*	27,700	See Appendix A for Details
B	CENTRAL BUSINESS DISTRICT	27,700	See Appendix A for Details
C	ARTERIAL	27,700	See Appendix A for Details
D	COMMUTER	27,700	See Appendix A for Details
E	COMPLETE ADB*	33,500	See Appendix A for Details
F	COMPLETE ADB*	21,575	See Appendix A for Details

* With minor modifications as required carried out on DND test track

TABLE 1

PARAMETER	VALUE
FUEL CLASSIFICATION	DIESEL #1
A.P.I. Gravity @ 15.5 deg. C	34.9
Heat of Combustion (BTU/gallon)	166,500
Flash Point (deg. C)	78
Sulphur %	0.28
Distillation (deg. C)	
IBP	192
10%	224
90%	281
FBP	350
Recovery %	99

TABLE 2: FUEL ANALYSIS - GULF 20X

3.0 TEST FACILITY

The test facility is located in the Test and Maintenance Facility (TMF) at the UTDC Kingston test site. The major features are described below.

3.1 FACILITY LAYOUT

The Experimental Test Area is located in a section of the TMF which satisfied the physical requirements for access, fuel supply and a safe operating area.

The layout of the test area is shown in Figure 1 where all rotating components are assembled on base frames and attached to an isolated concrete foundation pad. This pad is 8.22 m x 4.57 m and 45 mm thick with steel rod reinforcing. Vibration isolation is accomplished by installation of a 25 mm Rodofoam 6.R. isolation joint around the periphery of the slab with styrofoam insulation 100 mm thick on completed granular backfill under the slab. Anchor bolts for the test rig base frames are cast into the concrete slab.

A double concrete block wall encloses a control room which is located adjacent to the test area and provides for a safe, clean, low noise environment for test personnel and the electronic equipment of the data acquisition and control system.

3.2 TEST RIG STRUCTURE

The test rig structure is fabricated for securing to the concrete foundation pad and for mounting of the drive line components. The engine and its auxiliary components are bolted to one framework. The second framework holds the dynamometer. The torque sensor is fastened to a third framework.

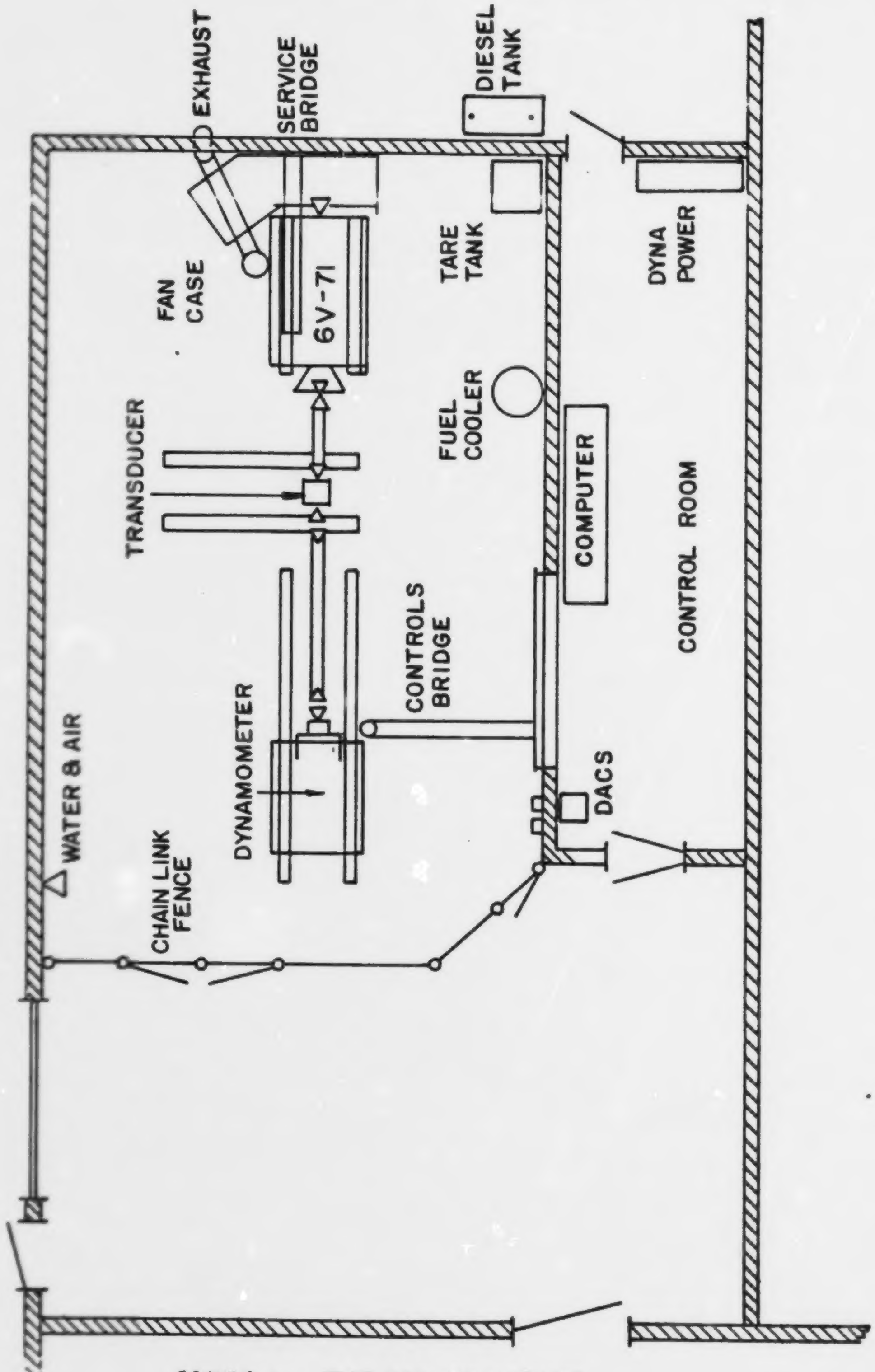

EXHAUST
SERVICE BRIDGE
DIESEL TANK
TARE TANK
DYNA POWER
FAN CASE
6V-71
FUEL COOLER
TRANSDUCER
COMPUTER
CONTROL ROOM
CONTROLS BRIDGE
DYNAMOMETER
DACS
WATER & AIR
CHAIN LINK FENCE

FIGURE 1: TEST RIG ARRANGEMENT

3.3 DYNAMOMETER

The dynamometer system consists of a DC electric machine and its controls. The dynamometer will operate as both a motor and a generator, speed and torque being controllable in both modes. The power characteristics of the machine are suitable for engines up to 120 Kw and a maximum torque of 1700 Nm, and is constructed to achieve rapid response to speed changes. Details are given in Table 3. Control of the machine is achieved by an electronic power conversion unit which is regulated by a variable dc supply of 0 to 10 volts. The control system will regulate the dynamometer speed from 0 - 316 rads/sec (3000 rpm).

3.4 DATA ACQUISITION AND CONTROL SYSTEM (DACS)

The data acquisition and control system provides the following functions:

- collection of data for analysis of factors pertinent to fuel consumption and performance of propulsion systems;
- individual control of dynamometer and engine CVT:
- monitoring operational parameters for alarm and communication of abnormalities or emergencies.

This system has sufficient flexibility to provide for the following additional functions:

- control system and strategy changes implemented through software;
- recording of all data:

Dynamometer

Model	BBC DC Machine GN 280S
Output Power	120 kW @ 1000 rpm
Maximum Torque	1655 Nm (0 to 530 rpm)
Overload Factor for Torque	1.9
Armature Voltage	400 to 750 V
Maximum Operating Speed	3000 rpm
Exciter Output	3700 W
Rotor Inertia	3.8 kg m^2
Weight	1160 kg
Ventilation	Separate with Fan on Top
Shaft Diameter	80 mm
Overall Width	0.8035 m
Overall Height	1.09 m
Overall Length	1.262 m

Controls

AC molded case breaker 600 am;
Veritron power converter type ZAD 3102 rated for
500 V AC input, 520 V DC, 650 A DC continuous;
Armature shunt ammeter and overload device;
Motor field supply type ASD 1202 for field weakening
operation;
Fused control transformer;
Isolation transformer Primary 575/3/60 delta,
Secondary 500/3/60 wye,
Rating 300 KVA.

TABLE 3: DYNAMOMETER CHARACTERISTICS

- indication of all data through the CRT;

- subsequent data analyses; and

- ability to simulate different vehicle configurations, i.e., system load parameters, such as vehicle mass, etc.

Figures 2 shows the make-up of the DACS as applied to the current test series.

A library of computer programs and software has been written for the test facility and was modified for the current program. The data acquisition, system control and data analyses required to implement the test program are contained in this library.

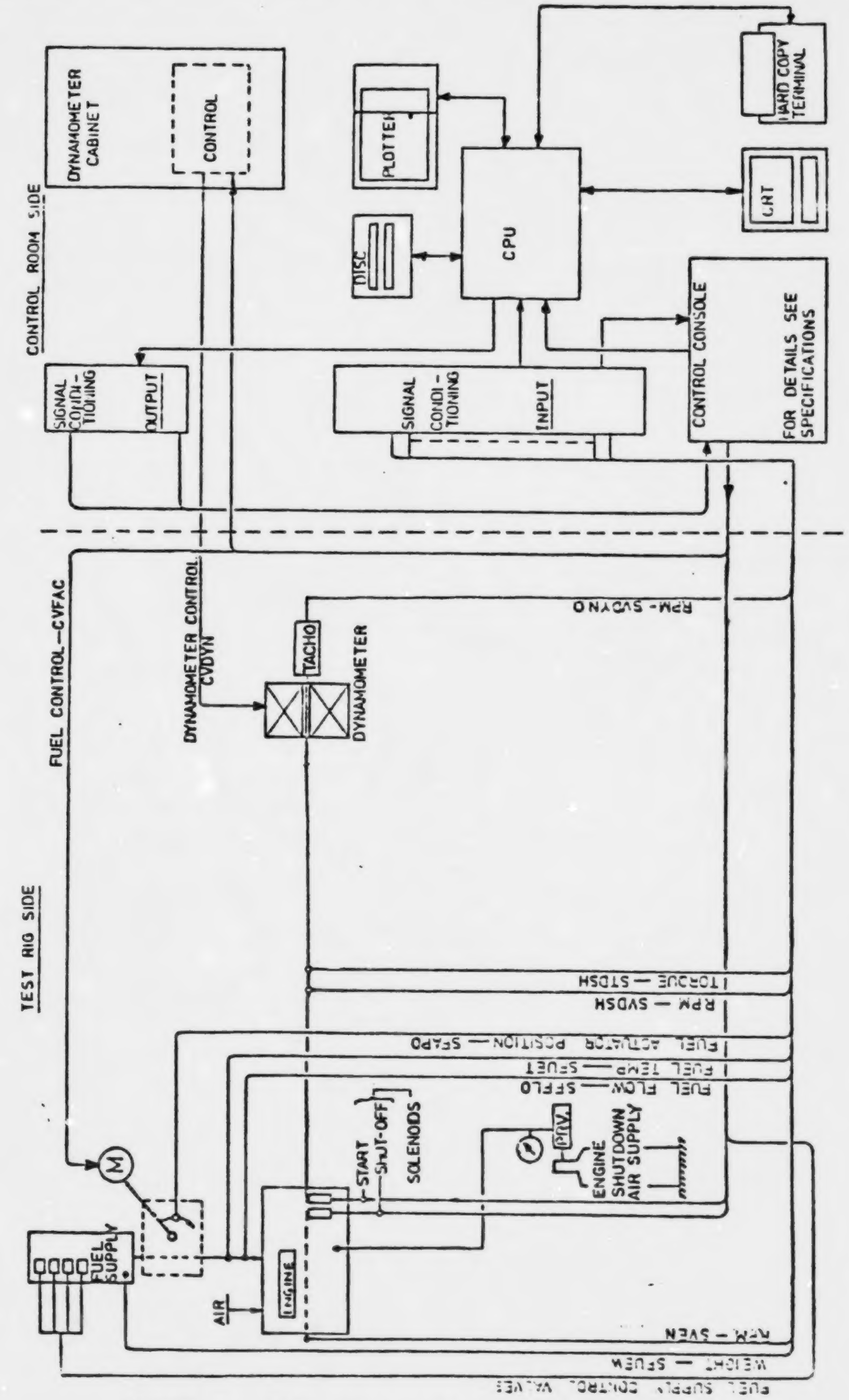
The software design embodies the following:

- display and record data in real time;
- execute preset decision logic and component execute component algorithms in real time;
- monitor operational parameters in real time;
- execute operator requests of a specific nature in real time;
- enable operator, via off-line data entry, to simulate vehicle and system load parameters;
- enable operator to prescribe for any test the duty cycle to be followed by the simulated vehicle; and
- perform selected data analysis off-line.

The software design and structure facilitates the flow of normal test procedure by being comprised of logical modules, viz., Prior-to-Test, Run-Test and After Test.

UTDC Research & Development Ltd.

Project Engine Test	Title DDA 6V-71 Test Report	Report No 552-630-012		
		Date 85.01.27	Issue 1	Page 10 of 38
		By J.H.S.	Appd	


CONTROL ROOM SIDE
DYNAMOMETER CABINET
CONTROL
PLOTTER
HARD COPY TERMINAL
DISC
CPU
CRT
CONTROL CONSOLE
FOR DETAILS SEE SPECIFICATIONS
SIGNAL CONDI- TIONING
OUTPUT
SIGNAL CONDI- TIONING
INPUT
TEST RIG SIDE
FUEL CONTROL—CVFAC
DYNAMOMETER CONTROL CVDYN
TACHO
DYNAMOMETER
RPM - SVDYNO
TORQUE — STDSH
RPM — SVDSH
FUEL ACTUATOR POSITION — SFAPO
FUEL TEMP — SFUET
FUEL FLOW — SFFLO
START
SHUT-OFF
SOLENOIDS
PRV
ENGINE SHUTDOWN AIR SUPPLY
M
FUEL SUPPLY
AIR
ENGINE
RPM — SVEN
WEIGHT — SFUEW
FUEL SUPPLY CONTROL VALVES

CONVENTIONAL BUS PROPULSION SYSTEM DATA ACQUISITION AND CONTROL DIAGRAM

FIGURE 2: DATA AQUISITION AND CONTROL SYSTEM LAYOUT

The "Prior-to-Test" Module includes:

- DAC system check-out;
- Operator test requirements entry;
- One-time data record;
- All systems "GO".

The "Run Test" Module is the real time part of the software and has a control cycle of one (1) second length. The following functions are executed during this cycle:

- Data scanning at a rate of one hundred (100) samples/sec.;
- Control execution at a rate of ten (10) samples/sec., i.e., calculation of pre-set control algorithms and subsequent command execution;
- Data recording at a rate of ten (10) samples/sec.;
- Monitor, once per second;
- CRT display update, once per second.

The "After Test" Module, includes:

- Recorded data examination;
- Selected data output in either graphical or print-out form;
- Development of routines for analysis as required.

The further degree of flexibility required has been achieved by segmenting the modules and routines into the following classes:

- controls:
- operation:
- test:
- data record: and
- operator display.

In addition the following benefits have been gained.

- dedicated, single function routines simplify writing, debugging and modifications:
- contained routines facilitate repeated use during developmental testing:
- multiple subroutine design simplifies sequence changes:
- software that must be re-written for a possible vehicle application is reduced.

3.5 FUEL SYSTEM

Fuel consumption is the primary parameter to be measured, therefore, accurate and repeatable measurements are a prerequisite. The system design to meet this requirement is shown in Figure 3.

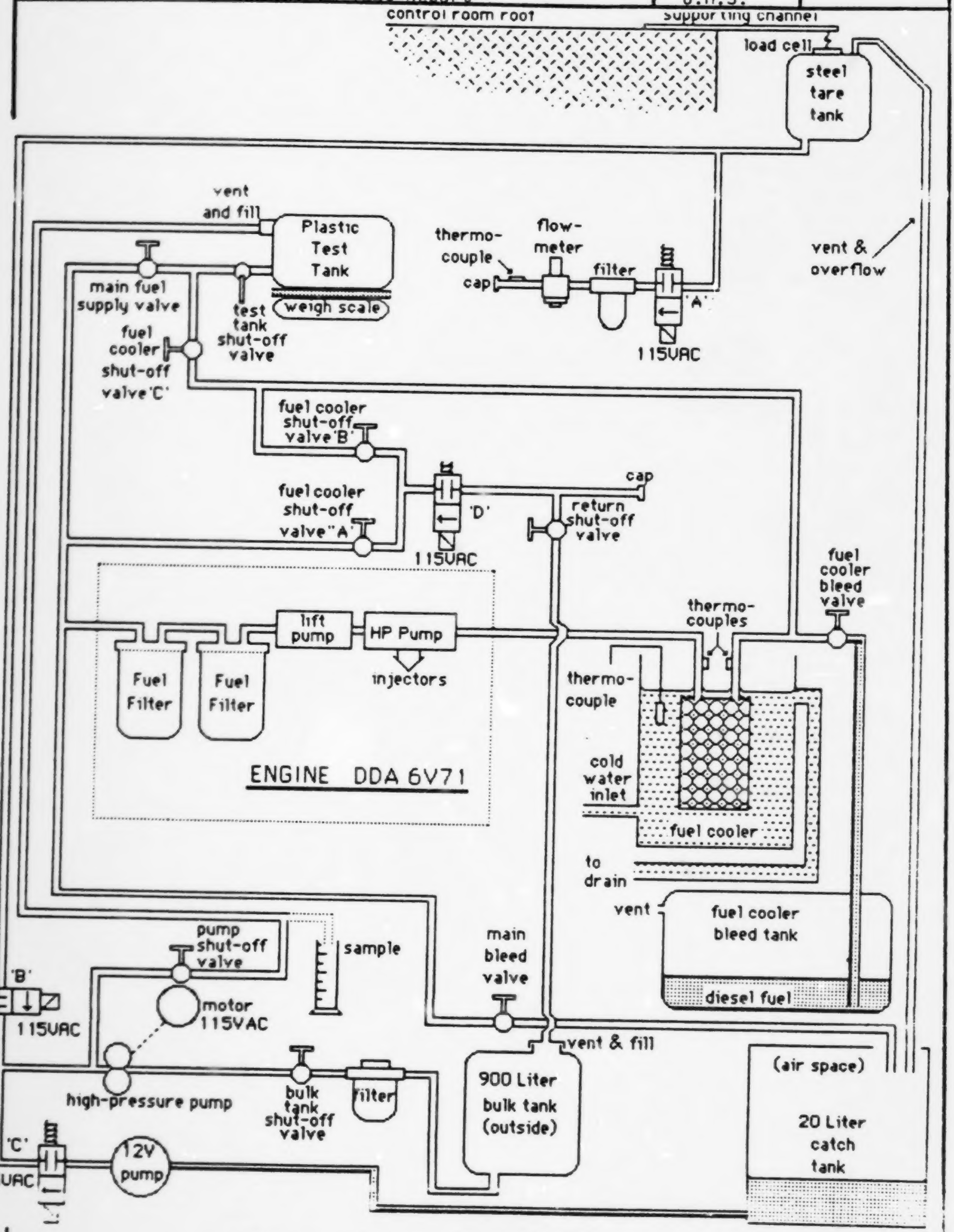

control room roof
supporting channel
load cell
steel tare tank
vent & overflow
vent and fill
Plastic Test Tank
weigh scale
main fuel supply valve
test tank shut-off valve
fuel cooler shut-off valve 'C'
thermo-couple
cap
flow-meter
filter
'A'
115VAC
fuel cooler shut-off valve 'B'
fuel cooler shut-off valve "A"
'D'
115VAC
cap
return shut-off valve
fuel cooler bleed valve
thermo-couples
lift pump
HP Pump
injectors
Fuel Filter
Fuel Filter
ENGINE DDA 6V71
thermo-couple
cold water inlet
fuel cooler
to drain
vent
fuel cooler bleed tank
diesel fuel
pump shut-off valve
sample
'B'
115VAC
motor 115VAC
main bleed valve
vent & fill
high-pressure pump
bulk tank shut-off valve
filter
900 Liter bulk tank (outside)
(air space)
20 Liter catch tank
'C'
115VAC
12V pump

FIGURE 3: FUEL SYSTEM ARRANGEMENT

To obtain an accurate fuel flow measurement it is necessary to prevent air entering the fuel lines. For this reason, the original weigh tank, capable of containing approximately 45 litres, was located ten (10) feet above the test installation, thus providing a good head to the flowmeter. In later tests a smaller tank of approximately 12 litres capacity and a weigh scale were used to obtain greater accuracy. The tare tank itself can be filled, using a manually activated high pressure pump from an outside storage with a capacity of 900 litres.

The diesel engine (a Detroit Diesel Allison 6V71) used in the first part of the program employs a continuous fuel flow technique to cool the injector valves on the engine. In a vehicle, some of the fuel entering the engine is consumed as fuel, the remainder of the fuel is circulated over the injectors to cool them and then returned to the fuel tank. Heat is imparted to the return fuel and the fuel temperature increases to 200 °F, before returning to the fuel tank where it is cooled. In a stationary application, such as the drive line tests where the fuel is returned to a small weigh tank, the fuel will become dangerously hot in a short time. Therefore, fuel cooling is essential to maintain its temperature at an acceptable level. For this reason, a heat exchanger is installed in the fuel return line and the fuel temperature is maintained in the range of 50 to 60°F.

3.6 EXHAUST SYSTEM

The exhaust system from the engine was designed to transfer exhaust gases outside the building without creating a back pressure on the engine. To offset any back pressure in the ductwork an exhaust extractor/ejector was incorporated which was operated from a compressed air supply.

4.0 ENGINE MAP TESTS

4.1 PROCEDURE

The following activities were conducted to develop an engine performance map:

- o Data Correction
- o Engine Warm-up
- o Engine test

4.1.1 Data Correction

The performance of a diesel engine is significantly affected by barometric pressure, temperature and humidity. Therefore, a correction factor must be applied to account for specific standard atmospheric conditions. For comparison with data from the manufacturer the SAE J270 Test Code was followed.

For this correction factor the following data is required:

- o Wet and dry bulb temperature before and after testing (use sling psychrometer).
- o Barometric pressure - obtain from TMF control tower.
- o Engine intake air temperature - use an average value, while test is in progress.
- o From steam tables find the maximum pressure exerted by steam at wet bulb temperature, Tw.
- o Find relative humidity using wet and dry bulb temperature readings. (Use psychrometric chart).

The SAE correction factor for diesel engines is as follows:

$$CF = \frac{P_s}{P_{tc}} \left[\frac{(T_t)}{(T_s)}\right]^{0.7} \quad \text{(Note: SAE J270 correction)}$$

Where;

P_s = Standard Ambient Barometric Pressure (99 kPa, 1atm)

T_t = Engine Air Inlet Temperature during test (in °K)

T_s = Standard Ambient Temperature (302.4°K)

P_{tc}= Corrected atmospheric pressure of dry air.

$$P_{tc} = P_t - [P_w - (6.6 \times 10^{-4})(P_t)(T_d - T_w)(1 - \frac{1.8T_w}{1571})]$$

Where:

P_w = Maximum pressure exerted by steam at temperature T_w, in kPa. (Obtain from standard steam tables).

T_d = Dry bulb temperature °C.

T_w = Wet bulb temperature °C.

P_t = Observed barometric pressure, kPa.

Sample Calculation

Test Data

P_t = 101 kPa

T_t = 31°C = 273 + 31 = 304°K

T_d = 31°C

T_w = 29°C

P_w = 4.55 kPa from steam tables

$$P_{tc} = 101 - [(4.55) - (6.6 \times 10^{-4})(101)(31 - 29)(1 - 1.8(29))]$$

$$= 96.58$$

Therefore:

$$CF = \left[\frac{P_s}{P_{tc}} \frac{(T_t)}{(T_s)}\right]^{0.7} = \frac{(99)}{(\ 96.58)}\left[\frac{(304)}{(302.4)}\right]^{0.7} = 1.029$$

If the observed power output, (P) of the engine was 110 kW, the corrected power would be as follows;

$$P_{cor} = (CF)(P)$$
$$= (1.029)(110) = 113.2 \text{ kW}$$

4.1.2 Engine Warm-Up

The manufacturers recommended warm-up procedure was followed to ensure that the engine reached the correct operating temperature prior to testing. This is necessary for proper steady state operation and the following represents the procedure utilized to achieve steady state conditions.

1. Start engine with no load (idle 600 rpm).
2. Set engine throttle at idle speed.
3. Set dynamometer to 10-15 HP load.
4. Check to see if operation is normal.
5. Increase engine speed to 1200 rmp.
6. Apply 42 HP load at 1200 rpm for 10 minutes.
7. Operating temperature should now be reached.

The engine warm-up procedure reported above was based on information obtained from the manufacturer's service manual. However, it was determined from tests that to ensure proper operating temperature the engine should be run at 1500-1700 rpm and, at half to three-quarters of maximum load for 45 minutes during Step 6.

4.1.3 Test Procedure

To generate engine performance maps it was necessary to measure the torque and the specific fuel consumption at specific throttle openings and engine speeds.

The engine was maintained at a constant speed while the throttle opening was varied from approximately 40% to 100% of maximum, in increments of 5%. (13 points). Then a new constant speed was maintained while the throttle opening was again varied from 40% to 100% of maximum, and so on for each engine speed. The engine speeds started at 600 rpm and increased in 200 rpm increments up to 2000 rpm, and one series at 2100 rpm for a total of 9 different engine speeds. Note that approximately 40% corresponds to the idle setting at each speed.

At each point the torque and the specific fuel consumption were measured. To measure the fuel consumption it was necessary to obtain the weight of the fuel by means of a load cell before and after a predetermined run time under steady state conditions. This provided a figure for the amount of fuel consumed during a standard time interval.

This procedure was repeated for all the engine speeds until all the data points had been obtained.

4.2 TEST RESULTS

The detailed engine test results are given in Appendix B. They are given in the form of corrected torque and power in Table B1 for the range of rack settings and engine speeds tested. In Table B1 the test results for brake specific fuel consumption are given. A more convenient form to study the results is shown in Figures 4 and 5. The results are shown in performance map format in Figure 6.

The best brake specific fuel consumption (bsfc) for the engine was 0.232 kg/kw-hr at a throttle setting of 75% at 1200 rpm and a power of 75.0 kW. Maximum measured power was 130.8 kW at 2000 rpm, when the bsfc increased to 0.271 kg/kw-hr.

Data was not available from the manufacturer in the form required for the engine with C-55 injector. Comparison of the minimum sfc point of each rpm curve for C-60 injectors with the measured data shows close agreement, and the shape of the curves is correct. This suggests that the 6V-71 test engine is in good condition. At 1400 rpm the sfc at the minimum agrees within 3%.

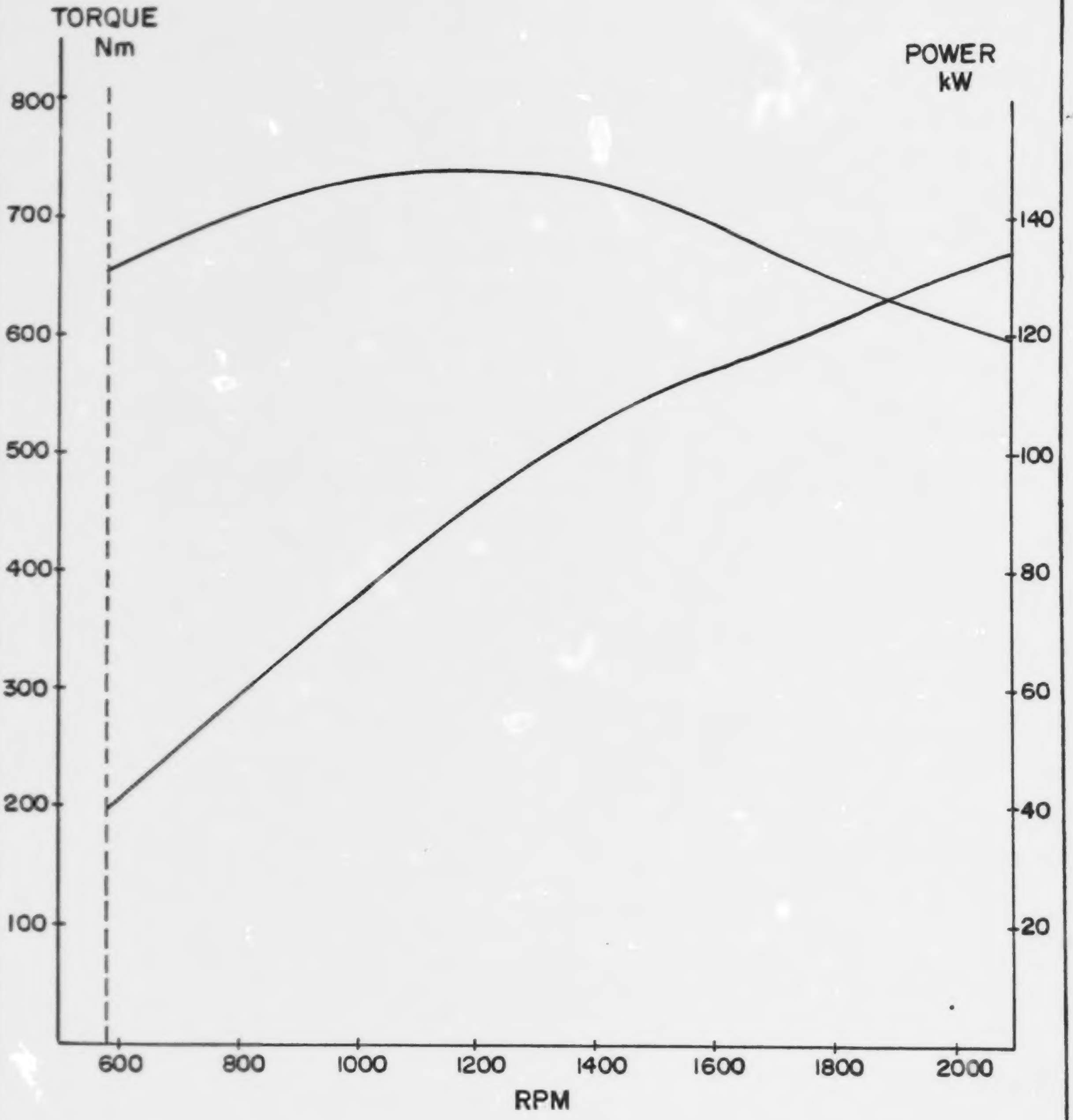


FIGURE 4: VARIATION OF TORQUE AND POWER OUTPUT WITH RPM AND RACK SETTING

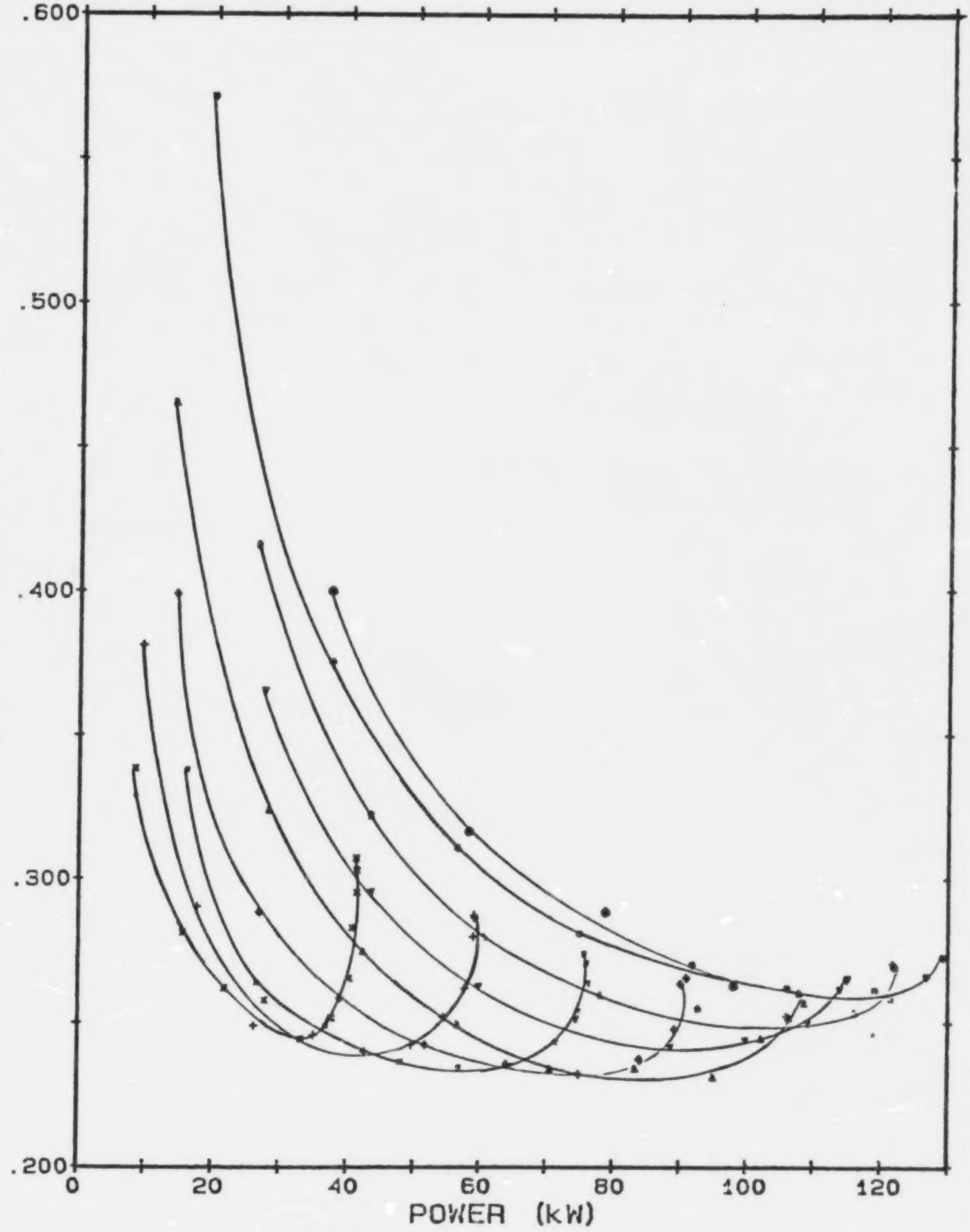


FIGURE 5: VARIATION OF BRAKE SPECIFIC FUEL CONSUMPTION WITH RPM AND POWER OUTPUT

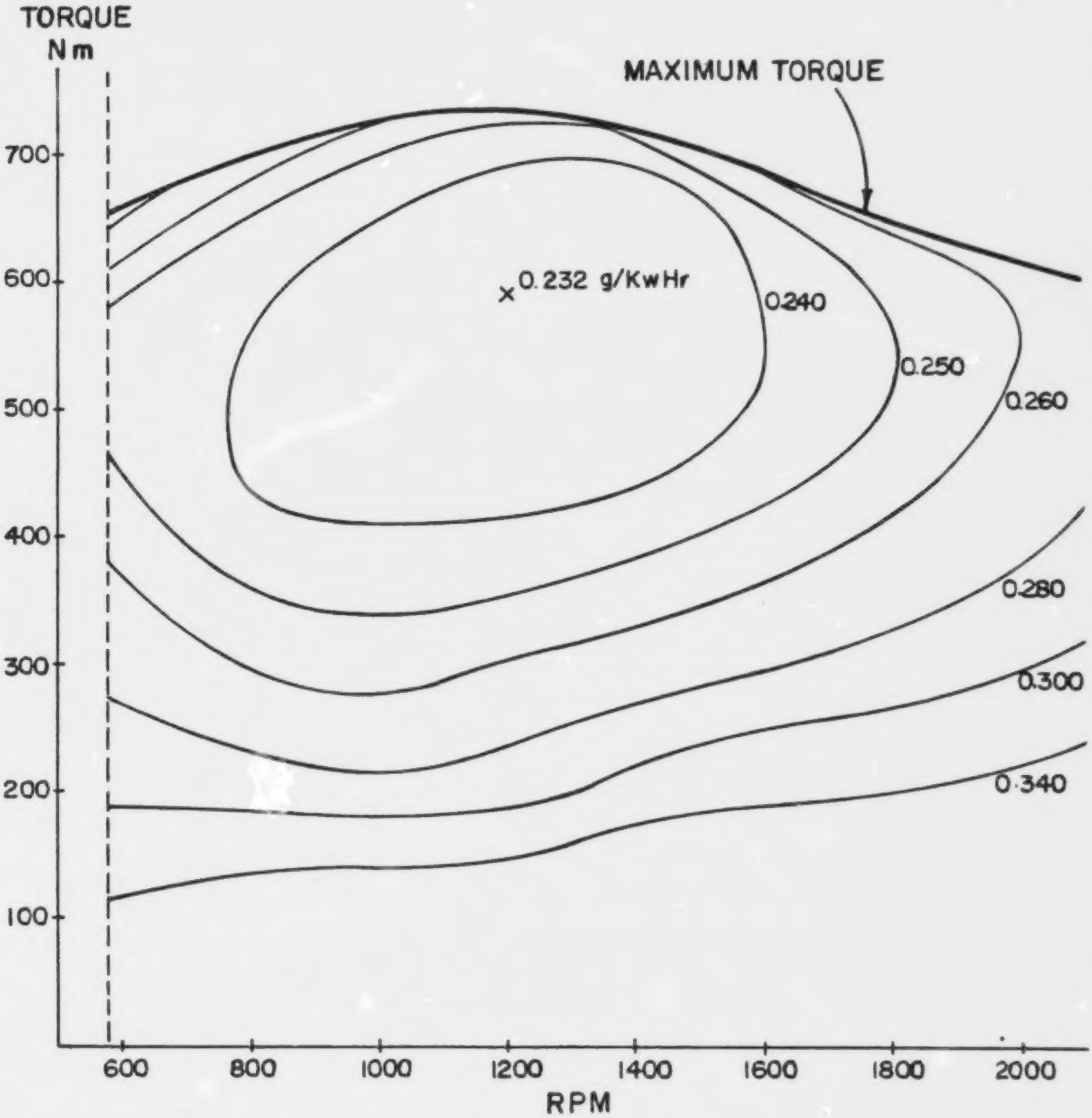


FIGURE 6: ENGINE PERFORMANCE MAP

5.0 ROUTE TESTS

5.1 GENERAL

This was performed after the route following program was rewritten and engine characteristics obtained from the performance map. Particularly, the engine torque versus speed characteristics were plotted and equations for these were generated. This information was introduced into the route following program to determine the throttle position under various operating conditions to produce required torque at the engine speed determined by the transmission characteristics.

After consideration of a number of operating methods the following was selected in order to increase repeatability.

- o Dynamometer (and hence engine) speed set by computer control to match stored profile.
- o Rack position (and hence fuel flow) set by computer control to match stored values.
- o The required engine speeds and rack positions were calculated off-line and the values stored on computer files.

5.2 PROCEDURE

Calibration of sensors: Sensor calibration included the torque and speed sensor Lebow Model 1105, No: 675. The first check was for the resistances across the terminals of the resistance bridge as specified in the manual that came with the sensor. The supplier calibrated resistor was then placed across the terminals of the bridge as specified in the manual and the supply measured for the excitation voltage. The DACS was then used to determine the digital readout for the corresponding torques simulated by the resistor. A straight line equation was then established to read torque at intermediate values and other values of the digital outputs (outside the range of the calibrating resistor).

The speed sensor was simply checked with a stroboscope for the accuracy of reading.

For fuel weight measurement, a Mettler PC 16 electronic balance was used. The balance is factory calibrated. The readings were checked with known calibration weights from the civil engineering laboratory at Queen's University.

The route tests were terminated when deemed necessary, for the following reasons:

1) Unsteady operating conditions of intake air temperature;

2) Unsteady coolant temperature;

3) Uneven performance of the engine;

4) Unusual sounds from the engine or dynamometer indicating a malfunction of the engine or dynamometer;

5) Axial movement of the torque transducer mounted flanges in the drive line;

6) Inaccurate readings as a result of failure to recheck the calibration of a transducer or resetting the throttle to zero.

7) Throttle clutch plate slippage.

8) Loss/lack of fuel during a run.

9) Loss of DACS control.

10) Running out of computer disc storage space.

5.3 TEST RESULTS

Examples of the overall vehicle and engine speed profiles used for the modified ADB cycle are shown in Figures 7 and 8. The central business district (CBD), arterial and commuter segments are shown in greater detail in Figures 9, 10 and 11.

In preliminary tests no attempt was made to control test cell or air inlet temperature. In later tests the air inlet temperature was controlled to 68°F ±3°F by varying the opening of the door from the test cell, since no intake air circulation equipment is fitted. Test results were discarded if the air inlet temperature varied outside these limits during a test, or engine temperature varied by ±3°F from a nominal 160°F. These limits correspond to SAE recommended values for fuel consumption measurements.

The tests were essentially operated in an open-loop, pre-programmed manner with both fuel rack and engine speed being controlled.

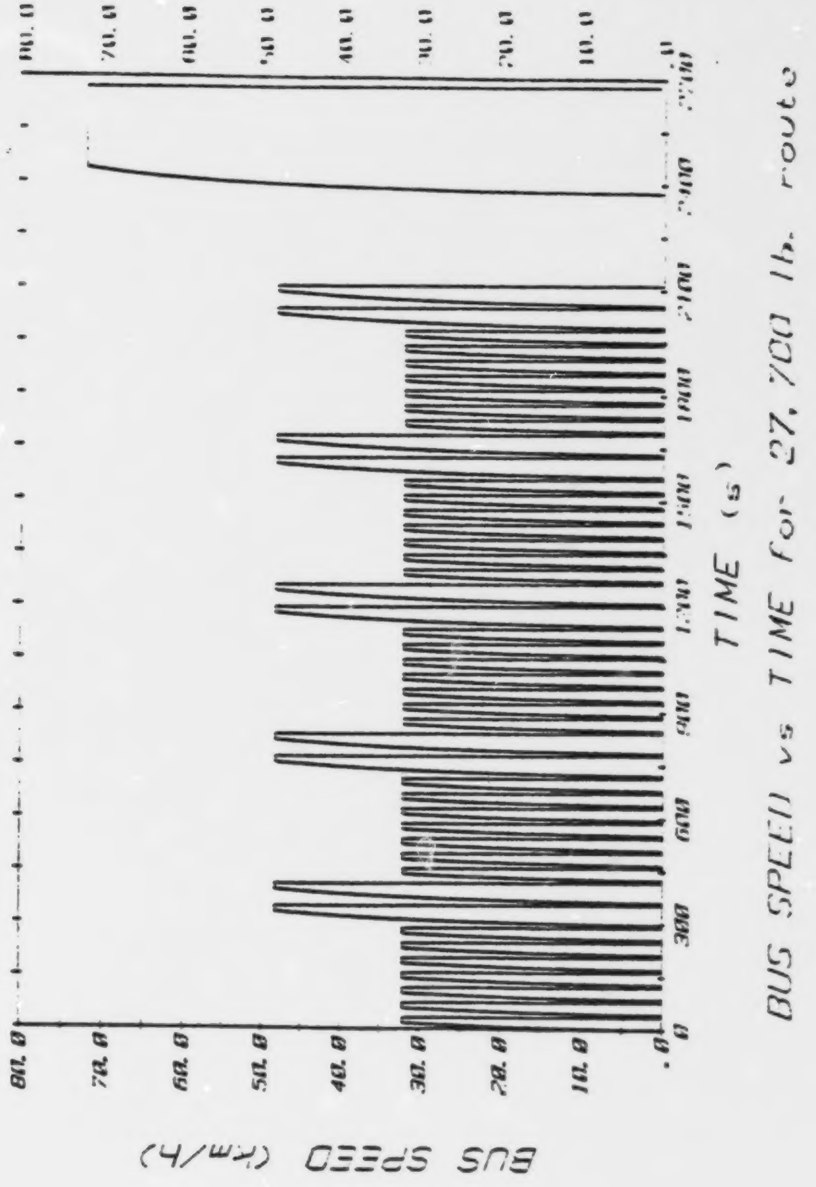


FIGURE 7: VEHICLE SPEED PROFILE, ADB ROUTE (MODIFIED)

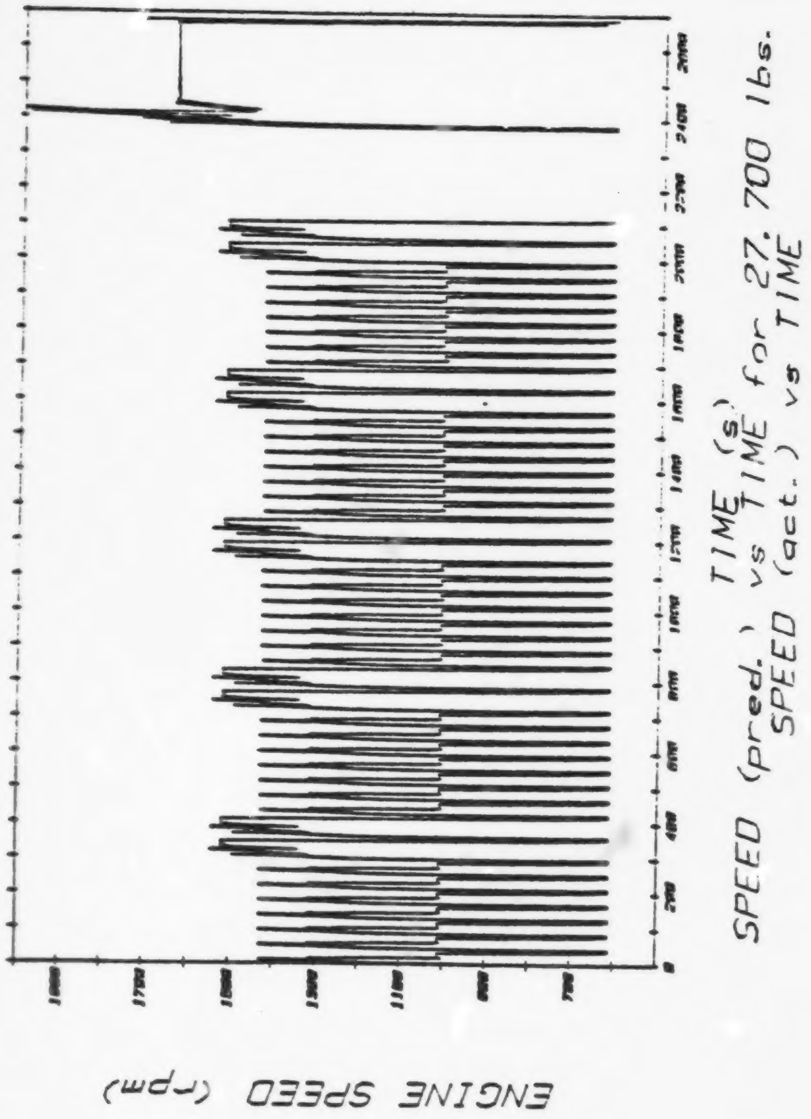
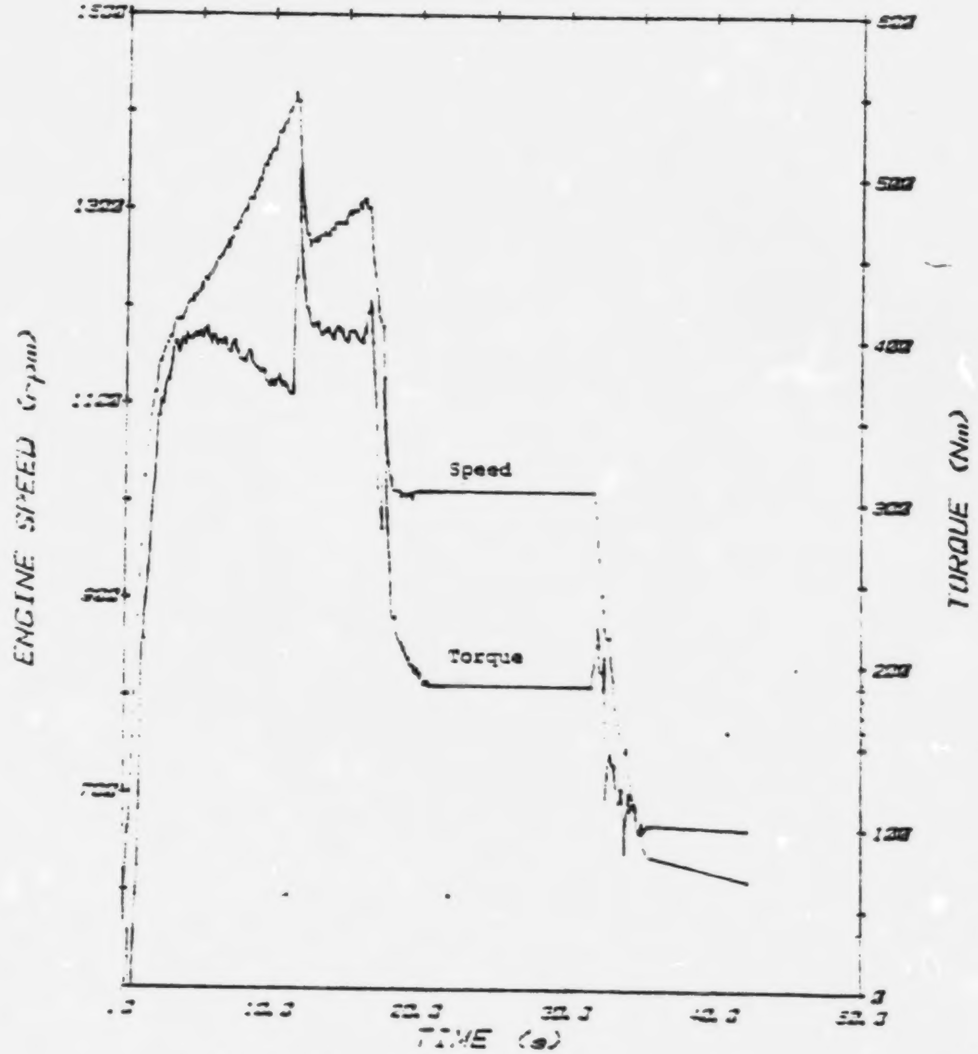
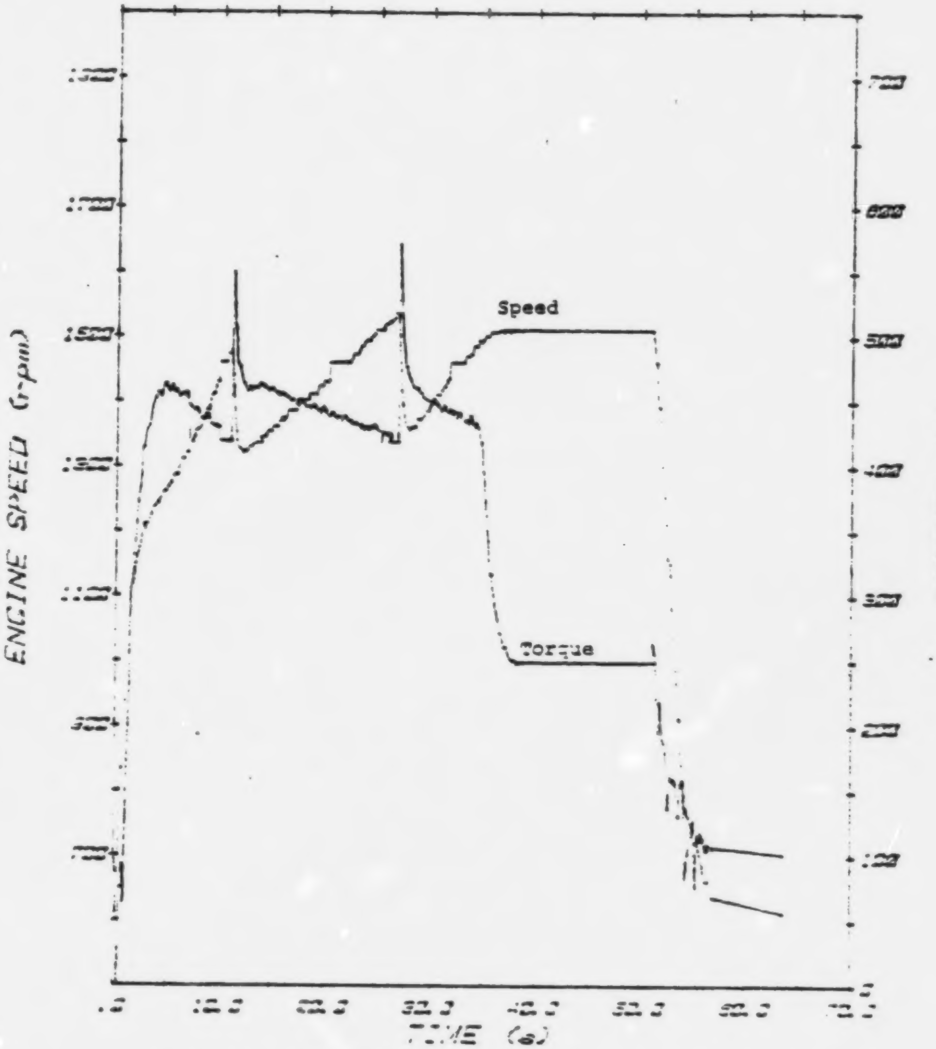


FIGURE 8: ENGINE SPEED AND TORQUE PROFILE, ADB ROUTE (MODIFIED)



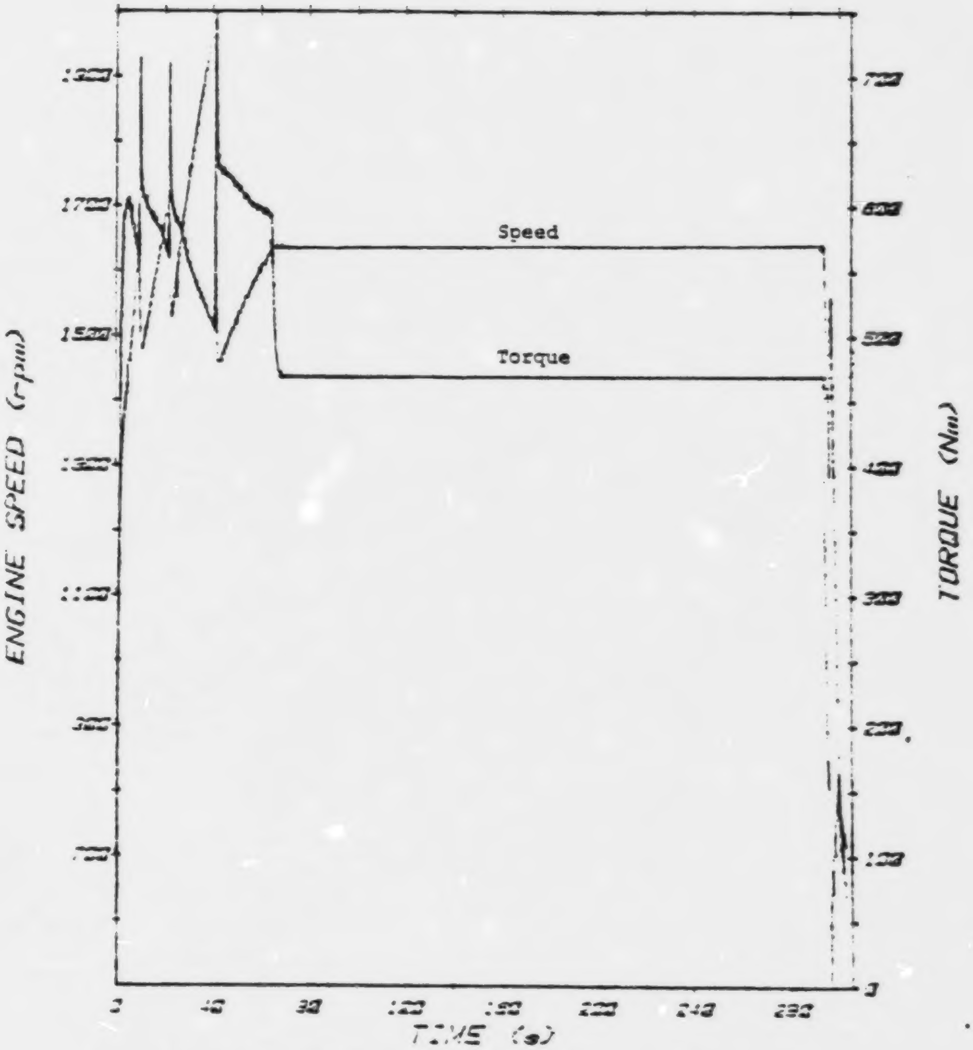
ENGINE SPEED and TORQUE vs TIME for CBD segment -- 27,700 lbs.

FIGURE 9: CENTRAL BUSINESS DISTRICT, ENGINE SPEED AND TORQUE PROFILE



ENGINE SPEED and TORQUE vs TIME for ARTERIAL segment -- 27,700 lbs.

FIGURE 10 ARTERIAL SEGMENT, ENGINE SPEED AND TORQUE PROFILE



ENGINE SPEED and TORQUE vs TIME for COMMUTER segment -- 27,700 lbs.

FIGURE 11: COMMUTER SEGMENT, ENGINE SPEED AND TORQUE PROFILE

The dynamometer speed control was very accurate, typically ±½% at all points of the route, therefore the only uncontrollable parameters are errors in fuel weight measurement (considered to be very small, much less than ½%) and in the amount of fuel injected. This last parameter can vary depending on:

o Error in position feedback potentiometer (small);

o Error in servomotor gearbox (small);

o Slip in servomotor clutch (checked every run);

o Free play in rack and injector position linkage;

o Variations in fuel temperature and hence density (small error).

It was concluded from the runs carried out that the sum of the potential errors in amount of fuel injected are of the order of ±2% during typical running at the average (and low) power settings typical of the ADB route i.e., of the order of 40 kW. This is largely a result of the unavoidable free play in the rack and injector position linkage and injector spindle position.

Test results obtained from test runs which met all the criteria set are summarized in Table 5. These results are also plotted in Figure 12, where the increase of fuel consumption with test weight is evident.

5.4 COMPARISON TO ROAD TESTS

Road test data supplied by OC Transpo resulted in a fuel consumption of 5.256 mpg + 2.73% - 2.52% for a series of five tests carried out at the LETE (Land Engineering Test Establishment) test track. This point is plotted on Figure 12 for comparison. The heating value of the test fuel used in the road tests is unknown, but from the specific gravity of 0.82 should be approximately 160,000 BTU/gal compared to the 166,500 BTU/gal for the UTDC test fuel. This would correct the test track data to 5.48 mpg and bring it much closer to the test cell results.

Since the test cell work is carried out under quasi-controlled conditions relative to test track work, and it was known that the test track was wet for some of the testing, it would be expected that the road tests would result in a higher fuel consumption than test cell work.

5.5 PARTIAL ROUTE TESTS

Fuel consumption was measured during the test run for each part of the ADB cycle at all three test weights resulting in the data recorded in Table 5. Excellent repeatibility between individual segments was obtained for tests carried out during one continuous run. For tests carried out on subsequent days (e.g., the commuter results) the scatter is of the order of ±2%.

VEHICLE WEIGHT	TEST DATE	MGP	AVERAGE MPG AND VARIATION	L/100 km AVERAGE
Empty Bus 9,807 kg (21,575 lb)	Nov. 13	6.65	6.48	42.6
	Nov. 14	6.46	± 2.5%	
	Nov. 19	6.33		
2/3 Loaded Bus 12,591 kg (27,700 lb)	Nov. 13	5.88	5.72	48.2
	Nov. 14	5.66	±2.9%	
	Nov. 19	5.55		
	Nov. 22	5.79		
Fully Loaded Bus 15,227 (33,500 lb)	Nov. 13	5.17	5.13	53.8
	Nov. 18	5.20	+1.2%	
	Nov. 19	4.94	-3.7%	
	Nov. 20	5.19		

TABLE 5: SUMMARY OF ADB ROUTE TEST RESULTS

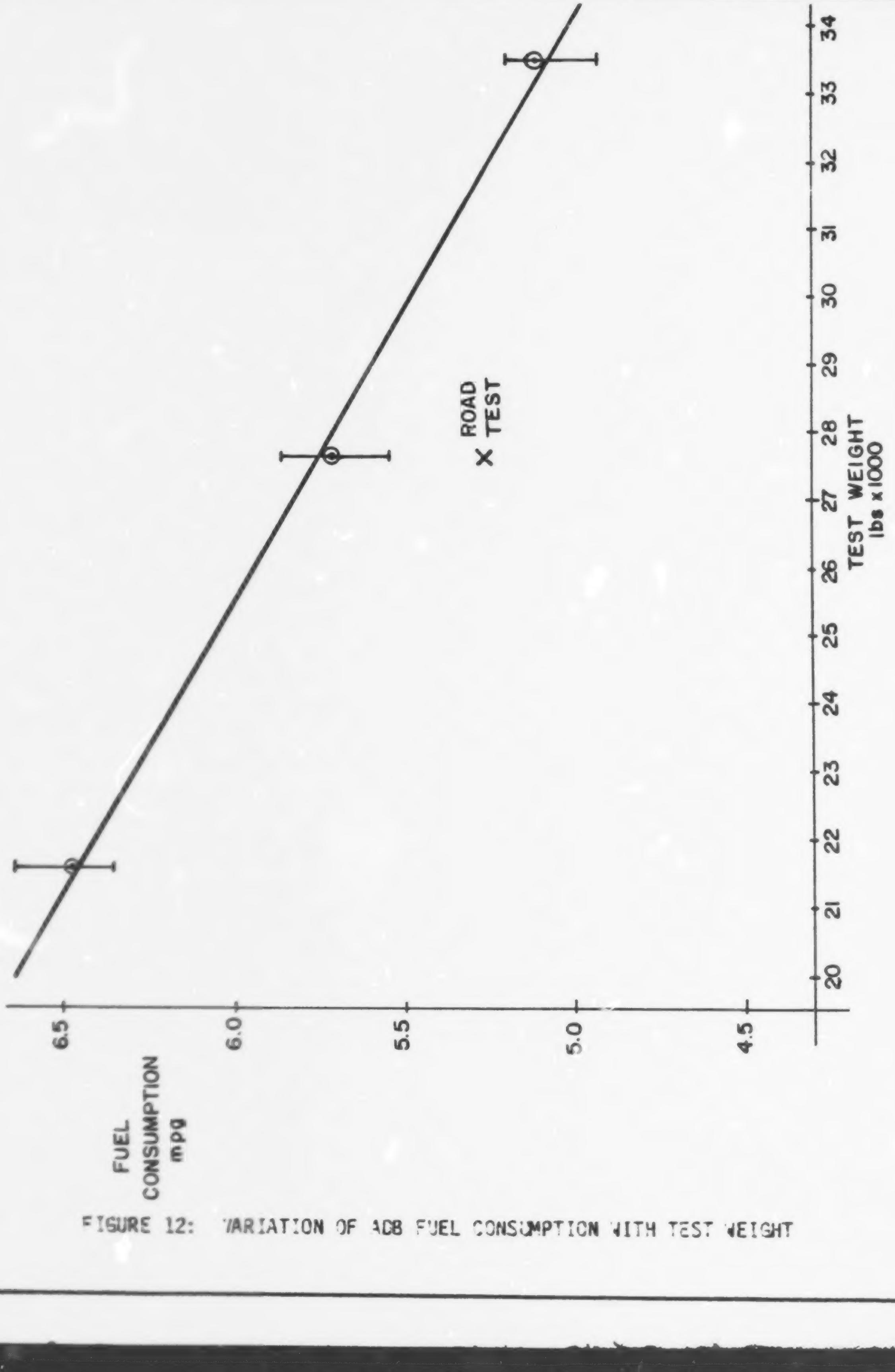


FIGURE 12: VARIATION OF ADB FUEL CONSUMPTION WITH TEST WEIGHT

5.6 EXHAUST MANIFOLD TEMPERATURE MEASUREMENTS

Exhaust manifold temperature was measured by an externally applied thermocouple mounted at the junction of the three arms of the rear bank exhaust manifold, immediately preceding the coupling to the exhaust pipe. The measurements were made for a series of engine operating conditions and are recorded in Table 6.

ROUTE	TEST	FUEL USED (GRAMS)		
		TEST WEIGHT 21,575 lbs	TEST WEIGHT 27,700 lbs	TEST WEIGHT 33,500 lbs
CBD	1	633.4 Nov. 14	738.1 Nov. 14	803.0 Nov. 13
	2	635.0 Nov. 14	738.3 Nov. 14	804.7 Nov. 13
	3	633.0 Nov. 14	739.5 Nov. 14	800.2 Nov. 13
	4	634.2 Nov. 14	738.9 Nov. 14	803.7 Nov. 13
	AVERAGE	633.9 +0.18% -0.14%	738.4 ±0.04%	802.9 +0.22% -0.34%
COMMUTER	1	1750.1 Nov. 5	1892.6 Nov. 13	2071.3 Nov. 13
	2	1701.2 Nov.13	1823.2 Nov. 14	2055.2 Nov. 18
	3	1743.2 Nov.14	1916.6 Nov. 19	2124.1 Nov. 19
	4	1757.7 Nov.19	1872.0 Nov. 22	2066.7 Nov. 30
	AVERAGE	1738.1 +1.1% -2.1%	1876.1 +2.1% -2.8%	2079.3 +2.2% -0.5%

TABLE 5: PARTIAL ROUTE FUEL CONSUMPTION

EXHAUST MANIFOLD TEMPERATURES - 5 MINUTES STABILIZATION	
CONDITION	TEMPERATURE °C
Normal Idle (565 rpm)	98
Fast Idle (1200 rpm)	94
70% Throttle and 1000 rpm	141
70% Throttle and 1500 rpm	145
100% Throttle and 2000 rpm	200

TABLE 6: EXHAUST MANIFOLD TEMPERATURE MEASUREMENTS

6.0 CONCLUSIONS

The following was concluded from the tests:

- The 6V-71 engine performance map tests produced fuel consumption results which agreed with the engine reference data and was of the expected form.
- The ADB route tests resulted in fuel consumption of the expected magnitude and with the projected trend of increased fuel consumption with added weight. Scatter was greater than expected, of the order of ±2.5%, and is largely a result of fuel injector control system variances.
- Partial ADB route tests resulted in good repeatibility from segment to segment.

It is expected that the IVECO diesel results will show better repeatibility based on the use of a brand-new fuel injector system and improved throttle positioner control.

UTDC Research & Development Ltd.

Project	**Title**	**Report No**			
Engine Test	DDA 6V-71 Test Report Appendix 'A'	552-630-012			
		Date	**Issue**	**Page**	
		85.01.27	1	1 of 5	
		By		**Appd**	
		J.H.S.			

APPENDIX 'A'

TEST SPECIFICATION

UTDC ENGINE DYNAMOMETER TESTING OF DIESEL AND PROPANE ENGINES
APRIL 6 198

STATEMENT OF TEST DETAILS

For each engine (DDA 6V-71 and IVECO 8220.02) defined in the contract the following tests shall be performed.

1) Engine Mapping

Fuel consumption for each of the 66 test points (defined below) shall be supplied, along with other pertient information recorded during the test (i.e., temperatures, pressures, etc.)

i) full load output power (gross*) will be determined at the following engine speeds - 600, 800, 1000, 1200, 1400, 1600, 1800, 2000, 2200, 2400, 2600 rpm (11 points). These figures shall be reported.

ii) at each of the speeds listed in i) above, the fuel consumption shall be determined at the following loads: idle, 20% maximum rated power (at rpm), 40% mrp, 60% mrp, 80% mrp, 100% mrp (full load). (6 points).

*gross power - no alternator, cooling fan, air compressor, air conditioning compressor or any other accessory loads.

2) Advanced Design Bus (ADB) Cycle

The ADB cycle is made up of four (4) different phases:

i) Central Business District (CBD);
ii) Arterial;
iii) Commuter; and
iv) Idle assembled as illustrated in Table 1.

Test Part	Phase	Number of Consecutive Runs each Phase	Approximate Phase Time (min - sec)
1	CBD	7	4-55
2	Arterial	2	2-07
3	CBD	7	4-55
4	Arterial	2	2-07
5	CBD	7	4-55
6	Arterial	2	2-07
7	CBD	7	4-55
8	Arterial	2	2-07
9	CBD	7	4-55
10	Arterial	2	2-07
11	Idle	1	4-23
12	Commuter	1	5-22

Total Time 44 min - 55 sec.

TABLE 1: ELEMENTS OF THE ADB CYCLE

Following is a detailed description of each phase.

i) Central Business District (CBD)

a) acceleration from rest to 32.2 kph (20 mph), full load.

b) cruise at 32.2 kph (20 mph) at constant reduced load.

c) deceleration from cruise to rest at a constant rate of 2.179 m/sec/sec (7.15 ft/sec/sec) at idle load

d) idle at rest for 7.0 seconds (simulated in "Drive" shift postion).

Total distance covered shall be 241.1 m (791 ft).

ii) Arterial

a) acceleration from rest to 48.3 kph (30 mph), full load.

b) cruise at 48.3 kph (30 mph0 at constant reduced load.

c) deceleration from cruise to rest at a constant rate of 2.179 m/sec/sec (7.15 ft/sec/sec) at idle load.

d) idle at rest for 7.0 seconds (simulated "Drive" shift position).

Total distance covered shall be 562.7 m (1,846 ft).

iii) Idle

Comprised of Idle load for 4 minutes + 23 seconds (simulated in "Neutral" shift position).

iv) Commuter

a) acceleration from rest to 72.4 kph (45 mph), full load.

b) cruise at 72.4 kph (45 mph) at constant reduced load.

c) deceleration from cruise to rest at a constant rate of 2.179 m/sec/sec (7.15/sec/sec) at idle load.

d) idle at rest for 20.0 seconds (simulated in "Neutral" shift position) then shut down.

The total distance covered shall be 5628.4 m (18,466 ft).

Vehicle Parameters

The following vehicle parameters shall apply for the entirety of the ADB test:

a) Simulated GCW shall be 1,2564.5 kg (27,700 lbs) for each engine.

b) The following accessories/systems shall be connected and operating:

- water pump
- cooling fan
- coolant thermostat set at 85°C (185°F)
- radiator
- 300 amp alternator feeding 50 amps continuously (at 12 volts) into a resistor.

The quantity of fuel consumed shall be determined by weight or other approved means which will ensure accurate measurement. These consumption figures shall be supplied for each ADB cycle run.

3) Simple Cycles

Two simple cycles shall be simulated under the same operating conditions as (2) above. These cycles shall be the CBD and Arterial Phases as described in (2) above.

Each test involves only one cycle and shall consist of back-to-back phases as many times as is necessary to ensure fuel consumption figures within the limits of the equipment used (±2% scatter-maximum).

As in (2) the fuel consumption shall be determined by approved means and shall be supplied for each test run.

UTDC Research & Development Ltd.

Project	**Title**	**Report No**		
		552-630-012		
		Date	**Issue**	**Page**
		85.01.27	1	1 of 9
Engine Test	DDA 6V-71 Test Report Appendix 'B'	**By** J.H.S.	**Appd**	

APPENDIX 'B'

ENGINE PERFORMANCE MAP RESULTS

TEST RESULTS

DATE OF TEST: 12 SEPT 84
TIME OF TEST: 14:22

TEST NO: EN01
TEST SPEED: 600 RPM

ENGINE SERIAL NO: DDA-6V71

DRY BULB TEMPERATURE: 70. F (21.1 C)
WET BULB TEMPERATURE: 58. F (14.4 C)
RELATIVE HUMIDITY: 41. %
BAROMETRIC PRESSURE: 101.55 kPa

NO	INTAKE TEMP	THROTTLE (%)		TORQUE (N-m)		POWER (kW)		FUEL FLOW	s.f.c.	
	F	Obs	Cor	Obs	Cor	Obs	Cor	g/s	kg/kW-h	lb/HP-h
1	87.	42.6	39.3	.04	.04	0.000	0.000	.41250		
2	86.	44.9	41.8	40.66	40.17	2.580	2.549	.55000	.7769	1.2772
3	88.	49.8	46.9	135.12	133.82	8.510	8.428	.79200	.3383	.5561
4	93.	55.0	52.4	248.45	247.64	15.710	15.659	1.22300	.2812	.4622
5	95.	60.0	57.7	345.09	344.83	21.910	21.893	1.59200	.2618	.4304
6	98.	65.0	63.0	436.83	438.15	27.760	27.844	1.99300	.2577	.4236
7	101.	69.9	68.2	523.44	527.00	33.040	33.265	2.25600	.2442	.4014
8	104.	74.9	73.5	591.02	597.27	37.380	37.775	2.63900	.2515	.4135
9	107.	80.0	78.9	628.38	637.38	39.800	40.370	2.97600	.2654	.4363
10	108.	85.0	84.1	637.77	647.71	40.160	40.786	3.20600	.2830	.4652
11	111.	90.0	89.4	644.36	656.82	40.720	41.507	3.40400	.2952	.4854
12	111.	94.9	94.6	642.34	654.76	40.570	41.354	3.52800	.3071	.5049
13	114.	100.1	100.1	641.69	656.50	40.520	41.455	3.48800	.3029	.4980

TABLE B1:

```
                                   EST   ULTS

      DATE OF TEST:  12 SEPT 84                              TEST NO:  EN02
      TIME OF TEST:  16:21                                TEST SPEED:  800 RPM

      ENGINE SERIAL NO:  DDA-6V71

                   DRY BULB TEMPERATURE:  70. F  (21.1 C)
                   WET BULB TEMPERATURE:  58. F  (14.4 C)
                      RELATIVE HUMIDITY:  41. %
                    BAROMETRIC PRESSURE:  101.55 kPa

 NO  INTAKE TEMP   THROTTLE (%)     TORQUE (N-m)        POWER (kW)     FUEL FLOW          s.f.c.
          F          Obs   Cor      Obs      Cor         Obs     Cor        g/s       kg/kW-h  lb/HP-h

  1      89.        43.9  40.7     2.19     2.17        .180    .179     .59500
  2      92.        49.9  47.0   114.41   113.89       9.560   9.517    1.00800      .3813     .6269
  3      96.        54.9  52.3   211.71   211.82      17.800  17.809    1.43600      .2903     .4772
  4      98.        60.0  57.7   311.78   312.72      26.270  26.350    1.82200      .2489     .4092
  5     101.        65.0  63.0   414.46   417.28      34.950  35.188    2.40200      .2457     .4040
  6     101.        70.0  68.3   502.88   506.30      42.460  42.749    2.84800      .2398     .3943
  7     104.        75.0  73.6   583.21   589.37      49.220  49.740    3.34900      .2424     .3985
  8     104.        80.1  79.0   640.44   647.21      54.130  54.702    3.82800      .2519     .4142
  9     111.        85.0  84.1   671.87   684.86      56.770  57.868    4.21100      .2620     .4307
 10     113.        90.1  89.5   683.70   698.63      57.830  59.093    4.59600      .2800     .4603
 11     124.        95.1  94.8   680.29   704.47      57.240  59.274    4.71700      .2865     .4710
 12     127.       100.0 100.0   677.54   704.14      56.930  59.165    4.72300      .2874     .4724
```

```
                                TEST RESULTS

      DATE OF TEST:  13 SEPT 84
      TIME OF TEST:  00:47                         TEST NO:  EN03
                                               TEST SPEED:  1000 RPM

      ENGINE SERIAL NO:  DDA-6V71

                      DRY BULB TEMPERATURE:  67. F  (19.4 C)
                      WET BULB TEMPERATURE:  63. F  (17.2 C)
                         RELATIVE HUMIDITY:  80. %
                       BAROMETRIC PRESSURE:  100.70 kPa

 NO  INTAKE TEMP    THROTTLE (%)     TORQUE (N-m)         POWER (kW)     FUEL FLOW          s.f.c.
          F          Obs   Cor       Obs        Cor       Obs       Cor       g/s         kg/kW-h  lb/HP-h

  1      89.         37.7  34.1        .69        .69      .070      .070     .77000
  2      90.         45.0  41.9      57.10      57.62     5.970     6.016    1.04100       .6230   1.0242
  3      91.         49.9  47.0     151.63     152.98    15.900    16.042    1.50500       .3377    .5552
  4      94.         54.9  52.3     250.98     254.18    26.250    26.585    1.94800       .2630    .4337
  5      95.         60.0  57.7     347.20     352.08    36.350    36.861    2.54400       .2485    .4085
  6      98.         65.1  63.1     449.81     457.85    47.130    47.973    3.14600       .2361    .3881
  7     101.         70.0  68.3     532.24     543.80    55.730    56.940    3.70400       .2342    .3850
  8     101.         75.0  73.6     603.48     616.58    63.260    64.633    4.21800       .2349    .3862
  9     106.         80.1  79.0     663.41     682.04    69.450    71.400    4.82300       .2432    .3998
 10     109.         85.1  84.2     691.71     713.77    72.440    74.750    5.27100       .2539    .4173
 11     114.         90.1  89.5     700.66     727.45    73.380    76.186    5.57000       .2636    .4333
 12     118.         95.1  94.8     696.09     726.23    72.850    76.004    5.71400       .2706    .4449
 13     117.        100.0 100.0     692.92     722.05    72.530    75.579    5.74600       .2737    .4500
```

```
                                  TEST RESULTS

    DATE OF TEST:  13 SEPT 84                          TEST NO:  EN04
    TIME OF TEST:  10:54                            TEST SPEED:  1200 RPM

    ENGINE SERIAL NO:  DDA-6V71

                       DRY BULB TEMPERATURE:  69. F  (20.6 C)
                       WET BULB TEMPERATURE:  64. F  (17.8 C)
                          RELATIVE HUMIDITY:  76. %
                        BAROMETRIC PRESSURE:  100.64 kPa

 NO  INTAKE TEMP   THROTTLE (%)     TORQUE (N-m)       POWER (kW)    FUEL FLOW          s.f.c.
          F         Obs   Cor      Obs       Cor      Obs      Cor      g/s       kg/kW-h  lb/HP-h

  1      97.        38.0  35.3     -.89      -.91    -.110    -.112     .96300
  2      96.        45.0  41.9     28.06     29.33    3.670    3.730    1.16800    1.1274   1.8534
  3      97.        49.9  47.0    113.39    115.30   14.270   14.621    1.60900     .3989    .6558
  4     100.        55.0  52.4    209.45    213.93   26.460   27.026    2.16400     .2883    .4739
  5      99.        60.0  57.7    303.76    309.07   38.330   39.102    2.80500     .2583    .4246
  6     101.        65.1  63.1    401.42    410.53   50.700   51.850    3.48900     .2422    .3982
  7     101.        70.0  68.3    496.34    507.60   62.730   64.153    4.19800     .2356    .3873
  8     106.        75.0  73.6    576.80    593.56   72.910   75.029    4.83600     .2320    .3815
  9     105.        80.1  79.0    647.10    665.08   81.790   84.063    5.54000     .2373    .3900
 10     113.        85.1  84.2    681.82    707.70   86.080   89.347    6.15100     .2478    .4074
 11     105.        90.1  89.5    694.75    714.05   87.780   90.219    6.60600     .2636    .4334
 12     112.        95.1  94.8    695.77    721.30   87.870   91.094    [illegible].72100     .2656    .4367
 13     114.       100.0 100.0    694.01    721.23   87.620   91.057    6.72300     .2658    .4370
```

TEST RESULTS

DATE OF TEST: 13 SEPT 84
TIME OF TEST: 11:46

TEST NO: EN05
TEST SPEED: 1400 RPM

ENGINE SERIAL NO: DDA-6V71

DRY BULB TEMPERATURE: 69. F (20.6 C)
WET BULB TEMPERATURE: 64. F (17.8 C)
RELATIVE HUMIDITY: 76. %
BAROMETRIC PRESSURE: 100.64 kPa

NO	INTAKE TEMP F	THROTTLE (%) Obs	THROTTLE (%) Cor	TORQUE (N-m) Obs	TORQUE (N-m) Cor	POWER (kW) Obs	POWER (kW) Cor	FUEL FLOW g/s	s.f.c. kg/kW-h	s.f.c. lb/HP-h
1	102.	39.7	36.3	1.04	1.06	.160	.164	1.19800		
2	101.	45.0	41.9	15.36	15.71	2.210	2.260	1.39100	2.2156	3.6424
3	101.	49.9	47.0	93.59	95.71	13.750	14.062	1.81600	.4649	.7643
4	103.	55.0	52.4	187.20	191.92	27.580	28.276	2.54100	.3235	.5318
5	104.	60.0	57.7	281.31	288.77	41.380	42.477	3.23600	.2743	.4509
6	108.	65.1	63.1	373.62	385.43	55.000	56.738	3.92300	.2489	.4092
7	115.	70.0	68.3	461.23	479.91	67.930	70.681	4.58500	.2335	.3839
8	114.	75.0	73.6	545.01	566.39	80.240	83.387	5.41100	.2336	.3840
9	118.	80.1	79.0	618.37	645.76	91.040	95.072	6.09400	.2300	.3794
10	109.	85.1	84.2	672.17	694.27	99.000	102.255	6.93700	.2442	.4015
11	116.	90.1	89.5	694.04	723.02	102.200	106.468	7.43700	.2515	.4134
12	128.	95.1	94.8	698.99	738.77	102.900	108.756	7.75600	.2567	.4221
13	122.	100.0	100.0	698.21	732.67	102.860	107.936	7.79900	.2601	.4276

```
                                    TEST RESULTS

    DATE OF TEST:  13 SEPT 84                          TEST NO:  EN06
    TIME OF TEST:  13:10                            TEST SPEED:  1600 RPM

    ENGINE SERIAL NO:  DDA-6V71

                     DRY BULB TEMPERATURE:  71. F  (21.7 C)
                     WET BULB TEMPERATURE:  65. F  (18.3 C)
                        RELATIVE HUMIDITY:  73. %
                     BAROMETRIC PRESSURE:  100.50 kPa

NO  INTAKE TEMP     THROTTLE (%)     TORQUE (N-m)          POWER (kW)       FUEL FLOW          s.f.c.
         F           Obs   Cor       Obs      Cor         Obs      Cor         g/s        kg/kW-h  lb/HP-h

 1      99.          43.9  40.7      -.52     -.53        -.090    -.092     1.53600
 2     100.          49.9  47.0     70.49    72.13       11.850   12.125     2.06400      .6128   1.0074
 3     100.          55.0  52.4    160.77   164.51       27.030   27.658     2.81000      .3658    .6013
 4     100.          60.0  57.7    253.92   259.82       42.680   43.672     3.58700      .2957    .4861
 5     101.          65.1  63.1    347.84   356.37       58.480   59.914     4.37600      .2629    .4323
 6     105.          70.0  68.3    430.17   442.91       72.350   74.493     5.20700      .2516    .4137
 7     106.          75.0  73.6    511.60   527.41       86.020   88.678     5.95700      .2418    .3976
 8     105.          80.1  79.0    577.28   594.38       97.040   99.915     6.78100      .2443    .4017
 9     102.          85.1  84.2    633.47   649.81      106.490  109.237     7.59600      .2503    .4115
10     103.          90.1  89.5    660.30   678.18      110.990  113.995     8.29800      .2621    .4308
11     105.          95.1  94.8    665.42   685.13      111.840  115.153     8.51000      .2660    .4374
12     109.         100.0 100.0    661.30   684.26      111.170  115.031     8.47400      .2652    .4360
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                                   TEST RESULTS

      DATE OF TEST:  13 SEPT 84
      TIME OF TEST:  13:45                          TEST NO:  EN07
                                                 TEST SPEED:  1000 RPM

      ENGINE SERIAL NO:  DDA-6V71

                     DRY BULB TEMPERATURE:  71. F  (21.7 C)
                     WET BULB TEMPERATURE:  66. F  (18.9 C)
                        RELATIVE HUMIDITY:  77. %
                      BAROMETRIC PRESSURE:  100.47 kPa

 NO  INTAKE TEMP   THROTTLE (%)     TORQUE (N-m)        POWER (kW)      FUEL FLOW          s.f.c.
          F         Obs   Cor       Obs      Cor        Obs      Cor       g/s       kg/kW-h  lb/HP-h

  1      102.       46.7  43.7        4.34     4.46       .830     .853   1.87000    7.9294   13.0358
  2      102.       55.0  52.4      136.56   140.20     25.800   26.503   3.06100     .4158     .6835
  3      102.       60.1  57.8      224.20   230.31     42.390   43.546   3.89500     .3220     .5294
  4      101.       65.1  63.1      312.41   320.53     59.110   60.646   4.70900     .2795     .4595
  5      109.       70.0  68.3      398.45   412.88     75.360   78.088   5.62500     .2593     .4263
  6      110.       75.1  73.7      472.86   490.58     89.360   92.709   6.56100     .2548     .4138
  7      112.       80.1  79.0      538.95   560.52    101.890  105.969   7.42000     .2521     .4144
  8      111.       85.2  84.4      591.28   614.20    111.740  116.071   8.16800     .2533     .4165
  9      106.       90.1  89.5      622.11   642.25    117.620  121.428   8.72600     .2587     .4253
 10      102.       95.1  94.8      627.00   644.09    118.520  121.751   9.14000     .2703     .4443
 11      105.      100.1 100.1      626.85   646.34    118.470  122.154   9.13700     .2693     .4427
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                              TEST RESULTS

     DATE OF TEST:  13 SEPT 84                          TEST NO:  EN08
     TIME OF TEST:  14:59                            TEST SPEED:  2000 RPM

     ENGINE SERIAL NO:  DDA-6V71

                    DRY BULB TEMPERATURE:  72. F  (22.2 C)
                    WET BULB TEMPERATURE:  66. F  (18.9 C)
                       RELATIVE HUMIDITY:  73. X
                     BAROMETRIC PRESSURE:  100.37 kPa

NO  INTAKE TEMP   THROTTLE (X)      TORQUE (N-m)           POWER (kW)       FUEL FLOW            s.f.c.
         F          Obs   Cor       Obs       Cor         Obs       Cor        g/s         kg/kW-h   lb/HP-h

 1       99.        49.6  46.7       2.28      2.33        .480      .492    2.26100       16.5587   27.2222

 2      101.        55.0  52.4      90.60     93.01      19.020    19.527    3.09900         .5713     .9393

 3      103.        60.1  57.8     174.31    179.40      36.570    37.638    3.92400         .3753     .6170

 4      105.        65.1  63.1     261.54    269.85      54.880    56.624    4.88800         .3108     .5109

 5      105.        70.0  68.3     346.53    357.54      72.730    75.041    5.85300         .2808     .4616

 6      111.        75.1  73.7     421.44    438.06      88.440    91.927    6.89800         .2701     .4441

 7      110.        80.1  79.0     487.43    506.03     102.270   106.172    7.72800         .2620     .4308

 8      116.        85.2  84.4     543.43    568.32     114.030   119.252    8.65700         .2613     .4296

 9      108.        90.1  89.5     583.61    604.39     122.480   126.841    9.38600         .2664     .4379

10      121.        95.1  94.8     592.26    623.15     124.290   130.772    9.83600         .2708     .4451

11      111.       100.1 100.1     592.58    615.95     124.360   129.264    9.79900         .2729     .4486
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                                 TEST RESULTS

      DATE OF TEST:  13 SEPT 84                          TEST NO:  EN09
      TIME OF TEST:  15:50                            TEST SPEED:  2100 RPM

      ENGINE SERIAL NO:  DDA-6V71

                     DRY BULB TEMPERATURE:  72. F  (22.2 C)
                     WET BULB TEMPERATURE:  66. F  (18.9 C)
                        RELATIVE HUMIDITY:  73. %
                     BAROMETRIC PRESSURE:  100.33 kPa

NO  INTAKE TEMP   THROTTLE (%)    TORQUE (N-m)        POWER (kW)      FUEL FLOW          s.f.c.
        F          Obs   Cor      Obs       Cor      Obs       Cor       g/s       kg/kW-h  lb/HP-h

 1     106.        49.9  47.0     3.84      3.97      .850      .878   2.43800     9.9912  16.4254

 2     103.        55.0  52.4    82.57     85.02    18.170    18.700   3.28500      .6321   1.0392

 3     101.        60.1  57.8   165.51    169.99    36.460    37.447   4.16000      .3999    .6575

 4     106.        65.1  63.1   256.25    264.83    56.430    58.319   5.12500      .3164    .5201

 5     104.        70.1  68.4   347.03    357.76    76.440    78.803   6.31000      .2883    .4739

 6     113.        75.1  73.7   425.90    443.96    94.080    98.070   7.16300      .2629    .4323
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APPENDIX D

MINUTES OF MEETINGS

MINUTES OF THE STEERING COMMITTEE MEETING - PROPANE BUS DEMONSTRATION

HELD TUESDAY, MARCH 27, 1984 AT 10:00 A.M.
IN THE OFFICES OF THE
OTTAWA-CARLETON REGIONAL TRANSIT COMMISSION

Present:

J.A. Bonsall - Chairman (OC Transpo)
W.D. Jenkins (OC Transpo)
O. Colavincenzo (Ont. Ministry of Transportation & Communications - Vehicle Systems)
✓J. Turner (MTC - Vehicle Systems)
K. Taylor (MTC - TEMP Program)
J. Heenan (Energy, Mines and Resources)
S. Murphy (Ont. Ministry of Energy)

1. The first quarterly report was reviewed in detail. Clarification of item 1.4.1 was requested in that the dummy Saurer engine was ordered to ensure that the final engine was capable of being installed into the engine compartment of the GM bus. The problem of reverse rotation of the engine was solved through internal engine changes. Item 2 also requires clarification in that the delays were not caused by the adapter, which is not connected with reverse rotation, but that the initial dynamometer testing indicated that the engine was lacking in power and would not reach a stable operating temperature. These problems have been overcome.

With these clarifications, the report was accepted.

2. M.T.C. requested that current fuel pricing in various Ontario areas be included in these minutes.

OC Transpo currently pays 38.68¢ per litre for diesel and 23.53¢ per litre for propane.

Current propane pricing in Toronto is 22.00¢ per litre, and EMR in Ottawa is paying 23.80¢ per litre. The current Ottawa retail price is 24.00¢ per litre, while the Toronto Transit Commission (T.T.C.) is paying 26.4¢ per litre.

Current diesel pricing at T.T.C in Toronto is 36.63¢ per litre; H.S.R. in Hamilton is paying 37.50¢ per litre and in Mississauga the price is 34.30¢ per litre.

3. The first Technical Report was reviewed and accepted. In future, the Quarterly Report will list all Technical Reports, their date and brief contents in a separate introduction section.

4. Compression Ratio data was requested for the diesel and propane engines:

IVECO 8220.02 : 10.9 to 1
GM 6V71 : 18.7 to 1

5. Because of the variations in pricing of diesel and propane across Ontario, it was agreed that Dr. R.F. Webb would prepare a short report on this situation and give some indications of future pricing trends. OC Transpo will coordinate this report.

6. A strategy is to be prepared, again to be drafted by Dr. Webb, of reconverting a propane-engined fleet back to diesel-engined - at any point in the future. This strategy is to be available in the event that propane pricing fails to remain competitive with diesel pricing.

7. The committee unanimously agreed that the GO/NO-GO decision was GO.

8. The future engine developments are minor in nature and will be implemented by Dereco with input from OC Transpo. Examples are: the changing of the oil return line from the alternator to the engine sump; the positioning of the carburettor mixture controls in a more favourable position for adjustment.

9. The anticipated noise and vibration testing should be conducted with the assistance of an expert in this field. Mr. Bonsall is aware of a suitable candidate (Dr. George Thiessen of Ottawa) and OC Transpo will make contact with him.

10. Investigations are to proceed into which method of refuelling buses is the most cost effective during the period of the demonstration.

11. By the next meeting, MTC are to provide proposals for the media requirements for a possible launch in May 1984 at the International Alcohol Fuels Symposium in Ottawa.

12. MTC request that a cash flow chart be produced for the remainder of the Demonstration Programme.. OC Transpo will coordinate this item.

13. 1983/84 invoicing to MTC has been submitted in the amount of $237,050.00 and $75,507.00 for a total of $312,557.00. This amount includes 74% of the cost of the next 14 propane engines.

14. A letter is to be sent to the Commanding Officer at L.E.T.E. expressing our appreciation for the assistance given by his facility during the testing programme to complete Phase I of the project.

(Copy of letter attached to these minutes).

15. The next meeting is to be held on Monday, April 30, 1984 at OC Transpo offices.

16. Meeting adjourned at 12:30 P.M.

OC Transpo

EQUIPMENT DEPARTMENT
SERVICE DU MATERIEL

84/04/02

Colonel Perrin,
Commanding Officer,
Land Engineering Test Establishment,
c/o Department of National Defense,
101 Colonel By Drive,
Ottawa, Ontario

K1A 0K2

Dear Colonel Perrin,

As you may be aware, this Transit Commission is investigating the feasibility of using Propane as a fuel in transit buses.

The recent fuel consumption and acceleration testing carried out at your facility was accomplished speedily with very acceptable results. This was due, in no small measure, to the invaluable assistance that we received from you, and in particular, Messrs. D. Christensen, W. Ng and W. Martin of the Instrumentation Engineering Section.

We hope you will convey to all concerned our sincere appreciation for a job well done. Many of those small problems, which can seriously affect any test programme, were overcome with alacrity, enabling us to recover some of the time lost due to the inclement weather.

If we caused you any inconveriance, we trust that it was minimal, especially during your exercise, and trust that we may approach you in the furture when we have a requirement to use a test-track facility.

Yours very truly,

W. Jenkins,
Equipment Engineer

WJ/kt

OTTAWA-CARLETON REGIONAL TRANSIT COMMISSION DE TRANSPORT RÉGIONALE D'OTTAWA-CARLETON
1500 BOUL. SAINT LAURENT BLVD. OTTAWA, ONT. K1G 0Z8 - TELEX 053-3628

2

MINUTES OF STEERING COMMITTEE MEETING
PROPANE BUS DEMONSTRATION PROJECT
HELD AT OC TRANSPO 30 APRIL 1984

Present: J. Bonsall (OC Transpo) Chairman
O. Colavincenzo (Ont. Min. of Transportation & Communications)
J. Turner (MTC)
J. Heenan (EMR)
P. Newgard (OC Transpo)
W. Jenkins (OC Transpo)
R. Webb (Consultant)
Cynthia Taylor (Synergistics Ltd.) - Part time

1. Minutes of Previous Meeting

The minutes were accepted with provision that a sentence be added noting that a 1.7 propane-to-diesel fuel ratio had been achieved in the fuel consumption test of the acceptance tests (which had a maximum target of 1.8).

2. Media Events and Schedule

The preliminary description of the project prepared by Synergistics Ltd. was made available and the proposed program was discussed. It was agreed that premature release of publicity based on short-term results from one propane bus could damage the project and particularly could affect the acceptance of propane buses at other properties. The following program was agreed upon:

2.1 Preparation by Synergistics of a technically-based information kit which could be made available to the press and to the enquiring public in the event that they requested information. W. Jenkins agreed to provide Synergistics with further information for the kit, to review publicity and to advise on the audiences to whom the literature should be addressed.

2.2 Mr. Heenan will provide a list of external parties to whom literature and technical data on the kit should be sent. Mr. Colavincenzo agreed to provide a list of recipients in Ontario.

2.3 No active promotion was to be undertaken before the full 15 bus fleet was available. Publicity is to be assembled for November 1984. A November 1984 meeting in Ottawa of the Canadian Urban Transit Association (CUTA), which will be hosted by OC Transpo, is a suitable time and place for initiation of the publicity program.

2.4 When in service and not involved in the post-November publicity campaign the 15 buses will have decals (car cards) inside each bus indicating the bus is involved in the propane demonstration project jointly funded by EMR and the Energy Demonstration group (Enerdemo) of the Province. Externally the buses will carry a simple sign "Propane" in addition to the mandatory windscreen certification sticker.

2.5 If required by Federal or Provincial groups involved, an announcement could be made of the fact that a demonstration had been initiated at OCT.

3. Technical Papers

A subcommittee was established for technical papers and publications comprising Mr. Colavincenzo, Mr. Jenkins and Dr. Webb. The group was to prepare and review papers for the November 1984 or February 1985 (most likely) SAE meeting: 3 papers were suggested reflecting engine technology (Dereco), testing (MTC and UTDC) and operational experience (OCT). Similar papers were to be available for presentation at the November CUTA meeting. These would be needed by October 1984.

4. Technical Reports

Technical Report #2 "Report of Fuel Economy Tests of OC Transpo LPG-Engined City Bus" was accepted.

A report on comparative prices of diesel and propane was reviewed and revisions will be made:

i. to express the price on a ratio basis (not on a percentage basis) to facilitate comparison of price and consumption ratios
ii. to add information on propane and diesel fuel taxes.

A report on the strategy for reconversion of propane buses to diesel buses is in preparation.

A report on propane engine developments, including the prospects for improved fuel economy and power level adjustments, is in preparation.

A report on tank design (see item 6) is planned.

5. Noise and Vibration Testing

The noise and vibration testing program will be reviewed with Professor Thiessen before the planned June tests at LETE. The results of the tests are to be included in the November technical papers (CUTA, SAE).

6. Improved Test Design

Although no problems have been encountered, a new shielding and a revised structure of the manifolded 4 fuel tank assembly are planned.

New tank coatings developed by Chrysler are to be investigated (DND and MTC contacts with Chrysler).

A report on tank design will be issued. It was noted that a diesel bus had its fuel tank/lines sheared recently by impact with an open manhole cover.

7. UTDC Program

The tests now proposed include:

- Programmed dynamometer tests of a standard GM 6V71 diesel engine - now started.
- Test of an Iveco propane bus engine to be started when the next engine is available in August 1984.
- Test of an Iveco 4-stroke diesel engine under a separate program funded by MTC and not included in the present propane bus demonstration project or budget.

8. Current Status of Project

The operation of propane bus #7930 on Route 1 is now routine. Performance was reported by Mr. Jenkins to be remarkably free of incidents. Good acceptance of the bus by drivers was reported.

A detailed log on the bus operations is to be maintained and the format reviewed/revised before the 15 propane buses are in service. This would include a record of incidents, fuel economy.

The work on the bulk fuel storage system and garage changes for propane will be initiated shortly and an appropriate engineering company engaged.

Fuel suppliers are being contacted to provide quotations on fuel and assistance in the selection of storage and bulk fuel delivery techniques.

Hovey Associates of Ottawa have been requested to provide a quotation for the preparation of drawings and instructions for the manufacture of the propane engine/cradle assembly and engine/fuel system interfacing and a separate quotation for the production of 15 sets of the interfacing hardware (cradle, tubing, piping, connectors, valves).

TES Ltd. (Sheffield Road, Ottawa) was suggested as a competent second source: quotations will be sought from TES.

9. Training

Since the Algonquin College course is full in 1984, it was agreed that courses be given at OC Transpo to train selected staff for the S6A licence endorsement with the examination to be taken at Algonquin. It was agreed that an experienced and qualified propane mechanic (Mr. Gauvreau) be retained to give the courses. Gauvreau's course material will be reviewed and supervised by R. Webb.

14. Other Business

The revised format of the project Cash Flow Schedule was accepted.

15. Next Meeting

The next meeting of the committee will be at 9.30 a.m. on Tuesday 12 June 1984 at the St. Laurent offices of OC Transpo.

To: W. Jenkins - OC Transpo 23 April 1984

From: R.F. Webb

Subject: Propane price, diesel price forecast

1. Current Prices to Bus Properties Using Propane and Diesel Fuel

Telephone enquiries have provided the following prices to properties as of 16 April 1984:

	Diesel ¢/litre	Propane ¢/litre	Diesel/propane price ratio %(volume basis)
TTC	36.03	24.2	1.49
Kitchener Transit	38.9	21	1.85
Brantford Transit	38.2	25.4	1.50
Cambridge Transit	39.4	20.2	1.95
London Transit	34	24	1.42
North Bay Transit	29.4	22.5	1.31
Oshawa Transit	36.75	25.6	1.44
OC Transpo	37.18-38.68	23.53	1.58-1.64

It should be noted that the propane prices do not reflect volume purchases and may include charges for local storage, whereas diesel fuel prices represent large volume contract sales of diesel fuel without added storage tank costs. Suppliers in Ottawa have indicated a bulk contract price for propane in the vicinity of 20.5-21.5¢/litre can be negotiated which would provide a diesel/propane price ratio of 1.8. The recent track tests of the propane bus by OC Transpo gave a fuel consumption ratio of 1:1.7 diesel to propane which indicates that propane will be the less expensive fuel where diesel/propane price ratios are higher than 1.7.

However, the fuel economy of the OC Transpo propane bus was measured at very low temperatures and is expected to improve when averaged over the year. The proposed tests will tell. Also the price of diesel fuel is depressed by over- supply due to the recession.

2. Price Spread of Propane

The price of automotive propane varies among the bus properties from 21¢/litre in Kitchener to 25.6¢/litre in Ottawa. In Ottawa, the retail price varied from a low of 22¢/litre (Superior Propane) to a high of 25.9¢/litre (Mannion Gas) among the 9 outlets in the city.

3. Future Prices

The price of diesel fuel is expected to rise from present levels due to a real increase after inflation in the price of crude oil of about 2% per year after 1986 when increasing quantities of OPEC oil must be used as North Sea and Alaskan sources have passed their peak output and international demand for oil increases again when higher levels of economic activity are reached. The Shell prognosis concurred to by Conoco is for a real price increase after inflation of 33% in the period 1986-93 and 85% or so when inflation is considered, i.e. the price of internationally traded crude will increase from the current |36 Cdn. per barrel to |66 Cdn. per barrel. These increases occur within the anticipated useful life of diesel and propane buses now being added to the fleet.

The price of diesel fuel in the late 1980's will reflect this change, together with additional charges due to investments which must be made to maintain diesel quality as the proportion of poorer stocks of crude oil (Canadian syncrude and heavy oil) increase and the demand for diesel increases faster than the demand for gasoline. Without inflation the added cost to maintain quality is conservatively forecast at 1.5¢/litre. The 1993 price of diesel fuel is therefore expected to be around 49¢/litre in constant 1984 dollars. With 4% annual inflation included the price will be about 75¢/litre.

The price of propane in the period to 1993 is not expected to increase at the same rate as that of diesel fuel. The bulk of propane production in Canada is from natural gas which will continue to be in surplus supply. New propane-rich sources from the east coast Venture field are certain to be added in the period to 1993.

The potential decrease in propane supplies from Canada's refineries will be offset by processing of heavier crudes. In total, Canada's propane production will increase in the period to 1993. Production of propane outside Canada comes from the processing of both natural gas and in oil recovery. Propane production from OPEC sources will greatly exceed supply and there is no expectation of rapidly increasing international or Canadian demand for the product for transport use or for chemicals. This world oversupply is expected to hold down the price of propane and will affect the values received by Canada for its large exports of propane - currently 45% or so of Canadian production.

The wholesale price of propane in Alberta is controlled primarily by the export price and this will be contained by the world surplus. However, other costs for transportation, storage and distribution are significant and will not be controlled by the export conditions.

The costs involved in the purchase and transport of propane have been calculated as follows for a Toronto location:

	¢/litre	
Alberta price, bulk	13.39	
Pipeline tariff to Sarnia	0.74	
Storage, freight, handling	2.46	(Dome charges)
Sarnia price bulk	16.6	(Dome charges)
Transport Sarnia to Toronto (rail)	1.40	
Terminal costs	1.30	
Price ex terminal	19.30	
Local transport (road)	0.70	
Vehicle fuelling costs	3.20	
Total retail	23.20	

For a large consumer the price could be in the range 20.5-22.2¢/litre.

For Ottawa slightly higher transport costs are involved but the increase may be absorbed within the vehicle fuelling cost margin by certain marketers.

The bulk price of propane in Alberta in the future is expected to be constrained by the export price and OPEC competition. The costs of freight and other items are expected to increase in line with inflation but not at the inflation + 2% annual rate anticipated for diesel fuel. Given that the Ontario and federal governments do not change their policies on the taxation of propane, the expectation is that the price of propane in Canada will grow in line with inflation plus about 1% per annum (reflecting competition with gas and heating oils). This formula leads to a 1993 price of propane in Ottawa of about 24.2 ¢/litre in constant 1984 dollars or about 34¢/litre with a 4% annual inflation rate included. The comparisons therefore are:

	1984	1993 (1984 $'s)	1993 with 4% annual inflation
Contract price diesel fuel Ottawa	38.68-37.18		
Averaged diesel	37.93	49	70
Contract price bulk propane	20.5-21.5		
Averaged propane	21	24.2	34.1
Cost Ratio diesel/propane (volume)	1.8	2.02	2.05

Thus, while the price of propane and diesel will fluctuate, the long term trend indicates substantial savings will be available from the use of propane in place of diesel fuel. The uncertainties regarding fuel supplies and prices, which may be occasioned by future events in the Middle East and OPEC policy, bear most heavily on imported crude oil-based diesel fuel. The price of propane, on the other hand, will be less vulnerable to such activities, since that commodity is a domestic product.

4. Fuel Taxes

The current price of diesel fuel includes a variety of federal taxes on crude oil, oil products and on propane, provincial royalties and taxes levied by the producing provinces (Alberta primarily) and provincial road taxes.

The taxes on finished products diesel and propane sold in Ontario in ¢/litre are:

	Diesel	Propane
Federal sales tax	3.0	0.07
Federal excise tax	-	N/A
Canadian ownership charges	0.72	0.36
Gas liquids tax	N/A	0.38
Ontario Road Tax	9.3*	-
TOTAL TAXES	13.02	0.81

* Basis 27% of average fuel service and self-service retail price (excluding provincial road tax) of diesel fuel. Varies.

5. Vehicle Tax

No provincial taxes payable on buses originally equipped for propane or on propane engines. The potential saving to OC Transpo in purchase of a propane-engined bus would be 7% of the bus price of about $165,000, i.e. $11,500.

OC Transpo

84/5/29

Mr. J. E. Turner,
Ministry of Transportation
And Communications,
1201 Wilson Avenue,
Downsview, Ontario.
M3M 1J8

Dear Jeff,

Please find enclosed the minutes of the Second Steering Committee meeting, together with the Amended "Pricing Report".

Will you please arrange to circulate copies at your end.

Yours very truly,

W.D. Jenkins, P. Eng.,
Equipment Engineer

/dl

cc: O. Colavincenzo
S. Murphy, (Ministry of Energy)
J. Graham (Ministry of Energy)
K. Taylor (Temp)
J.A. Bonsall (OC Transpo
P. J. Newgard (OC Transpo)

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JUN 7 1984
Vehicle Systems Office
Transportation Technology &
Energy Branch

3

MINUTES OF STEERING COMMITTEE MEETING

PROPANE BUS DEMONSTRATION PROJECT

HELD AT OC TRANSPO 5 JULY 1984

Present: J.A. Bonsall (OC Transpo) Chairman
O. Colavincenzo (Ont. Min. of Transportation & Communications)
J. Turner (MTC)
K. Taylor (invited guest from MTC)
Ms. J.E. Bell (invited guest from Ont.Min.Ener. part-time)
J. Murphy (Ont. Ministry of Energy)
J. Heenan (EMR)
P.J. Newgard
W.D. Jenkins - Project Manager
R.F. Webb - Consultant
Cynthia Taylor (Synergistics Ltd.) part-time (invited guest)

1. Minutes of Previous Meeting #2

Paragraph 2.4 of the minutes of the previous meeting was corrected to indicate that the project is jointly funded by EMR and the Ontario Ministry of Energy. With this change the minutes were approved. It was also agreed that the minutes should note the actual composition of the project committee.

2. Media Material and Schedule for Release of Material

The draft publicity material provided by Synergistics Ltd. was reviewed, the title changed to "Propane in Transit" and suggestions from all present were recorded for incorporation in further drafts.

It was agreed that the Synergistics representative (Cynthia Taylor), together with W. Jenkins and R.F. Webb, would revise the draft press release, the press backgrounders, and the draft brochure. The revised texts were to be submitted to members of the committee for their review with the comments to be provided to Mr. Jenkins, who would then authorize completion of the literature with appropriate suggested changes included.

The principal points agreed upon were:

Draft Press Release and Press Backgrounder

OC Transpo will assign a person to receive and respond to press enquiries. The funding statement in the press release will indicate funding by EMR and the Ontario Ministry of Energy with technical support from MTC.

Brochure

Statements concerning the following were suggested for addition/change:

- Project funding by EMR/Ministry of Energy.
- Cost containment as a propane substitution objective to be included.
- Other advantages of propane to be included which are not dependent upon current tax concessions on alternative fuels.
- Transit buses consume a significant portion of Canada's transport diesel fuel supply.
- Linkage of propane cost to natural gas to be omitted.

Other editorial and technical points now included in revised text.

Car Card

It was agreed that car card display in the propane buses would display only the Enerodemo and OC Transpo logos. The title of the project would be given for the brochure "Propane in Transit".

Schedule for Release of Material

The schedule for release of the above material and related publicity was set for November 1984. Some of the material would be made available for issue with technical papers being prepared by OC Transpo, MTC and the engine supplier (DERECO) which will be delivered at the October 1984 annual meeting in Ottawa of the Canadian Urban Transit Association. It was agreed that disclosures and press releases before the CUTA meeting would adversely affect CUTA member response to propane conversion outside Ottawa.

3. Propane Supply, Storage and Site Change Status

Very satisfactory quotations had been received from the two major suppliers, Superior Propane and ICG Ltd. Both permit cost savings over the current price of diesel if the propane fleet in service achieves or exceeds the fuel economy demonstrated in the trials which were reported previously. The final decision on the fuel supplier was dependent on receipt of a bid from Petro-Canada and review of the other aspects of the fuel supply/support package.

The actual quotations on propane received were disclosed, but in confidence.

Mr. Bonsall stated that with the fuel supply mode now defined, he would authorize consultant architect services to begin the investigation of site changes needed for fuelling, storage and repair of the propane bus fleet.

4. Staff Training Program

OC Transpo had organized and conducted on-site the training program needed to qualify OC Transpo staff for engine/vehicle conversions to propane (S6A examination). It was expected that a high proportion of the staff at the courses would pass the examination held at Algonquin College.

5. Delivery Schedule for Engines and Bus Conversions

There had been delays at the supplier DERECO which will necessitate air freight of the next 2-3 propane engines, with the remainder delivered by container. The supplier has agreed to complete deliveries on an urgent basis with completion before November 15.

A major engine rebuild program on conventional engines is scheduled by OC Transpo which may require farm-out of the installation of some of the propane engines.

6. Noise and Vibration Tests

Pass-by and interior noise tests were completed. Some change in the exhaust muffler is required to bring the noise level at the rear of the bus down to or below the level experienced with the diesel bus. Elsewhere the noise level is lower than with the diesel, and is acceptable.

Hovey and Associates have been retained to complete and interpret noise tests (in addition to their $5,391 contract to provide drawings of the engine assembly, cradle and re-engining operation).

The results with the propane bus in service are very encouraging: the passenger perception is positive.

7. UTDC - Engine Testing

UTDC is behind schedule. They have the IVECO diesel engine at their facility but not tested. They will receive the next propane engine.

8. Technical Matters

8.1 Reconversion to Diesel. A short report on this is in preparation for August issue.

8.2 Propane Engine Developments. As for 8.1.

8.3 Tank Design. A revised shielded design has been received from Westeel. It was agreed that various coatings for the 15 propane bus tanks would be used. 5 vehicles would each be fitted with tanks finished:

(a) by phosphate treatment with undercoating
(b) shot blast finish, spray and conventional finish
(c) aluminum spray finish.

8.4 The propane/diesel fuel report had been reissued with the revisions suggested by the committee.

9. Other Business

The committee for the project was recorded as follows:

Chairman: J.A. Bonsall (OC Transpo)
Representing Ontario Min. of Energy: J. Graham or substitute.
Representing EMR: J. Heenan or substitute
Representing MTC: O. Colavincenzo, or substitute
Representing OC Transpo: P.J. Newgard
Project Manager: W.D. Jenkins (OC Transpo)
Consultant to Project: R.F. Webb

It was agreed that substitutes could be provided by the departments concerned and that guests could be invited to meetings but that their presence should be agreed upon by the Chairman of the Committee.

10. Next Meeting

Scheduled for 9.30 a.m. 11 October 1984 at OC Transpo, Ottawa.

7.8.84

4

MINUTES OF STEERING COMMITTEE MEETING

PROPANE DEMONSTRATION PROJECT

HELD AT OC TRANSPO 11 OCTOBER 1984

Present: J.A. Bonsall (OC Transpo) Chairman
O. Colavincenzo (Ont. Min.of Transportation & Communications)
J. Turner (MTC)
A. Doherty (EMR)
W.D. Jenkins (OC Transpo) Project Manager
R.F. Webb - Consultant

1. Minutes of Previous Meeting

The minutes of the meeting held at OC Transpo on 5 July 1984 were accepted.

2. Publicity on Demonstration

It was reported that the revisions have been incorporated into the draft publicity material prepared in conjunction with Synergistics Ltd. and this is now being reproduced for issue to the Steering Committee.

Mr. Bonsall provided the outline of the technical approach to publicity that OC Transpo wishes to pursue. OC Transpo plans to present two papers and a demonstration of propane buses to members of the Canadian Urban Transit Association on 21 November 1984 at the Annual General Meeting of CUTA. 300-400 people are expected to be at the technical session (Skyline Hotel) and demonstration.

The committee discussed the opportunity this provides for an official announcement of the demonstration and release of publicity material by representatives of the federal and Ontario ministries.

Mr. Doherty will bring the opportunity for an opening ceremony on 21 November to the attention of the Minister of Energy, Mines and Resources and will also advise Transport Canada. EMR will advise OC Transpo through Mr. Jenkins, and Ontario ministries through Mr. Colavincenzo. Mr. Colavincenzo will advise the Ontario ministries of Energy and Transportation and Communications and affect liaison with EMR.

Mr. Jenkins will instruct Synergistics Ltd. on the production of copies of the media material (1000 suggested) and their issue to EMR and the Ontario ministries for release on 21 November.

It was agreed that technical papers would be presented at a future meeting of the Society of Automotive Engineers, but no date was set.

3. Presentation to CUTA Meeting 21 November at the Skyline Hotel, Ottawa (scheduled for 10.15 a.m.)

Mr. Bonsall plans to present an introductory paper on the rationale for OC Trunspo interest in the propane bus demonstration; Dr. Webb a paper on conventional and alternative fuel trends which lead to the choice of propane; and Mr. Jenkins a paper prepared with Mr. Newgard of OC Transpo on the experience to date with the propane bus and fuel system. A panel discussion is scheduled to follow the presentation of papers.

4. Technical Status Report

4.1 Operations

There were no problems to report with the first propane bus, which is temporarily out of service while Hovey and Associates are preparing engineering drawings to facilitate future bus re-engining with the Dereco propane engine. Driver response is positive; the public appears to be unaware of the presence of the propane bus, which bodes well for future public acceptance of propane buses in the system.

4.2 Delivery

Two further propane engines (#2,3) have been received; 6 are in transit by container ship and the remaining 6 engines are scheduled to arrive before December 1984. Conversions should be completed by 1 January 1985, when the full-scale demonstration program with 15 buses in service will be underway.

4.3 Inspection Visits

Mr. Jenkins reported on his visit to the engine supplier Dereco, which resulted in finalization of the propane engine specifications, confirmation of the delivery schedule, and acceptance of the production run for delivery to OC Transpo. Technical details of the engine were discussed (exhaust system, oil return, governing, settings). Mr. Jenkins reported that the Dereco staff are enthusiastic and are providing a high quality of involvement in the design and testing of their propane engines.

A report was given on the visit of OC Transpo engineering staff to Vienna Transit to examine their propane fleet, garages, fuel systems, safety equipment and procedures. A written visit report is to be prepared by Mr. Jenkins for OC Transpo.

4.4 Tank Design

15 new tank systems have been ordered from Westeel Corporation. In the bus the 800 litres of propane stored will meet 99% of the route requirements (which range from 200-600 km/day). The exception may be Route 99 with a long high-speed run on the Queensway to Kanata.

4.5 Re-engining Drawings

Work at Hovey is of good quality and on schedule for use with the new engines. Hovey is to produce drawings of the interconnections and engine installation in the bus and one prototype set of fittings. A separate contract is to be let for the production run of fittings.

4.6 Dereco Technical Service

OC Transpo will issue a work order to Dereco (within the approved budget item) to provide technical services for the period 13-22 November. Dereco staff will assist in the start-up of re-engining of the production series and be available for the CUTA demonstration.

4.7 Propane Fuelling Facility

The price offer from Superior Propane for the provision of propane during the demonstration period was substantially lower than those received from ICG and PetroCanada.

In addition to fuel supply, bidders were required to provide advice on fuel systems installation and safety. Superior provided the best offer in this regard with the offer to install the fuelling system substantially at its own cost, to obtain approval for the installation and to interface with OC Transpo staff and architects responsible for the pad for the fuel tank, the fuel island, the piping and electrical services. No local supplier was seen to be able to meet the requirements for fuel system supply, safety and other technical counsel, and bids for fuel supply from others will not be sought.

Based on the outstanding fuel price, the equipment and services offered by Superior Propane, OC Transpo had decided to award the contract to that company. OC Transpo staff will prepare the formal documentation after Mr. Bonsall has advised the Commission.

4.8 Staff Training

The first batch of 29 OC Transpo staff has obtained S6A certification. A program for S6B certifications is now being drawn up.

4.9 Safety Manual

A detailed manual and reference work has been prepared on propane safety. The manual was prepared by OC Transpo and the R.F. Webb Corporation under contract from Transport Canada. The meeting discussed the need for a short-form bulletin on propane safety for OC Transpo staff and a separate manual on fighting propane fires, which should be of interest to city and regional fire departments.

Mr. Jenkins agreed to commission the short-form bulletin under the existing budget, and to determine the response of the City of Ottawa Fire Department to the need for a manual and other training aids for propane fires.

4.10 UTDC Testing

UTDC has had technical difficulties with its equipment but is expected to complete testing before 1 January 1985.

4.11 Noise and Vibration Tests

The drive-by noise test procedure needs modification. A rerun of the noise tests will be made. A report on the tests to date is in preparation. This will be Technical Report #3.

4.12 Engine Conversion (Propane to Diesel) and Propane Engine Developments

These issues are discussed in Technical Report #4 which has been issued.

4.13 Quarterly Reports

Quarterly Report #2 was issued 1 October 1984. The report for July was omitted due to low activity in the program but reports will now be issued on a regular basis – the next on or before 1 January 1985.

5. Project Cash Flow and Schedule Report

Quarterly Report #2 contains details of the revised cash flow and project schedule. The major cash flow changes are due to:

1. The appreciation of the dollar with respect to the Swiss franc has saved on engine purchases.
2. The new manifold 4-vessel design of fuel tank has resulted in cost savings for the in-vehicle fuel system.
3. It has been decided to purchase upgraded vehicle test equipment.
4. Expenditures budgeted for the fuelling facility are reduced due to the offer of equipment on loan from Superior at no cost.
5. Architectural and drafting services related to item 4 are also reduced.
6. The computer program additions are to be absorbed by OC Transpo.
7. Slower than forecast delivery of propane engines has reduced 1984/5 expenditures for maintenance costs, project administration, training, and engineering staff assigned to the project. These deferrals in 1984/5 expenditure impact on both the MTC and OC Transpo budgets for 1984/5.
8. Due to the above, the contingency allocated will not be required in 1984/5. In total, expenditures to 31 March 1985 are now forecast to be $974,347, a reduction of $156,969 over the budget of $1,131,306.

The revised allocation of expense for 1984/5 is therefore:

	Prior Budget 1984/5	Revised Budget	Carry Forward to 1985/6 Budget
MTC Account	$556,559	438,100	118,459
OCT Account	213,800	175,300	38,500
Total	700,354	613,400	156,959

Discussion on the revised cash flow determined the following:

1. Extension of the demonstration period beyond 31 March 1986 will be considered in 1985. Extended testing in service will provide improved data and compensate for the slow start which has resulted in a short testing period for intermediate numbers of buses after the GO-NO GO decision (no significant delay has occurred in the concurrent testing of the entire 15 bus fleet).
2. OC Transpo will consider the purchase of additional spares for the propane engines (this can be done within the approved engine and technical service budget without further MTC approval).
3. It was agreed that a technical proposal should be prepared by OC Transpo concerning the investigation and preliminary design of an improved fuel metering and fuel control system designed to eliminate the safety hazard from fuel overfill.
4. Fuel tank spares should be purchased. Provision will be made in this for fuelling from the left and right-hand side of the bus.

6. Next Meeting

The next meeting of the Steering Committee was scheduled for 9.30 a.m. 13 December 1984 at OC Transpo.

TO JEFF

OC Transpo

84/11/13

RECEIVED
NOV 2 1984
[illegible]
Transportation Technology [illegible]
Library Branch

Ministry of Transportation
And Communications,
1201 Wilson Avenue,
Downsview, Ontario.
M3M 1J8

Attn: Mr. J.E. Turner,

SUBJECT: PROPANE BUS DEMONSTRATION PROJECT,
STEERING COMMITTEE MEETING
11 OCTOBER 1984

Dear Jeff,

Please find attached Minutes of the above meeting. Will you please circulate to members in Toronto.

Will you approve the enclosed invoice from UTDC so that payment can be effected.

Yours very truly,

W. Jenkins, P. Eng.,
Equipment Engineer

/dl

cc: O. Colavincenzo, ✓
J. Heenan,
S. Murphy

J.A. Bonsall
P.J. Newgard

OTTAWA-CARLETON REGIONAL TRANSIT COMMISSION DE TRANSPORT REGIONALE D'OTTAWA-CARLETON

5

MINUTES OF STEERING COMMITTEE MEETING
PROPANE DEMONSTRATION PROJECT
HELD AT OC TRANSPO 24 JANUARY 1985

Present: J.A. Bonsall (OC Transpo), Chairman
O. Colavincenzo (Ont. Min. of Transportation & Communications)
J. Turner (MTC)
K. Taylor (MTC)
J. Heenan (EMR)
S. Murphy (Ont. Min. of Energy)
W.D. Jenkins (OCT), Project Manager
R.F. Webb - Consultant.

1. Minutes of Previous Meeting

The minutes of the meeting held at OC Transpo on 11 October 1984 were accepted.

2. Report on Publicity and Public Events

2.1 Propane in Transit: Official Opening and Press Conference

The press releases, background explanation of the "Propane in Transit" program, were released at the press conference and the official opening ceremony for the program held at the Skyline Hotel in Ottawa on 21 November 1984.

The response to the program opening was judged to be satisfactory and consistent with the low-key strategy set by the program managers until extensive operating data has been accumulated. The opening and the press releases generated coverage in 2 local newspapers and local TV and radio programs. (The press clippings and further information on the press conference are included in the 3rd Quarterly Report on the program to be issued with these minutes).

It was agreed that the publicity contractor, Synergistics Ltd. has provided only adequate services. The arrangements for meeting the principals at the press conference were judged inadequate and too many reworks of the press kit were required due to a low level of technical expertise at Synergistics. The decal for use in the bus was judged to be of excellent quality.

Problems with publicity and public meetings may be reduced in the future now that OC Transpo has an official Public Relations Officer.

2.2 CUTA and Technical Publications

A series of papers on the propane bus demonstration was presented on 21 November 1984 on the occasion of a technical session at the annual general meeting of the Canadian Urban Transit Association. A description of the propane bus and a short ride on it were provided to CUTA members at the Merivale Garage on November 20.

There is substantial engineering interest among transit bus managers, but many remain sceptical of the long range cost savings, since they depend heavily on the Ontario tax concessions on propane fuel and vehicle sales tax.

The strategy for providing information for the transit industry and maintaining their interest was discussed. The three papers presented at CUTA to be issued to the Propane Demonstration Steering Committee as Technical Report #5 will be made available to CUTA for publication. An update on the demonstration will be offered for the 1986 CUTA meeting to be held in Montreal. A list of trade magazines and transit industry publications (including Transportation Forum) will be drawn up and papers released when data is available. It was suggested that an interesting publication for future release to SAE would include the details of work at OC Transpo and the comparative engine tests underway at UTDC.

3. Technical Status Report

Mr. Jenkins provided a report on the status of the project, the highlights of which follow.

3.1 Current Operations

The first two propane buses (7930, 7926) have operated well, with only the level of problems which are anticipated in the start-up phase of such a demonstration.

The problems encountered and solved have included a pressure switch failure in the new electrical subsystem which shows the driver the engine is running (the low noise level requires this); overheating of the alternator which was solved by grounding the alternator; leaks in fuel tank plugs. Cold starting has been a problem when the buses are stored outdoors overnight at -15°C or below, even when a block heater is used. The short-term solution which will be sought is to run the buses at intervals at below -15°C at night. The longer-term solutions involve equipping a dedicated area in the garage with detection and ventilating equipment to permit internal storage. In the meantime, other technical solutions to facilitate cold start (actually continued running of the engine after cold start is achieved) will be sought.

A report on the safety techniques and implications for storage of the propane buses inside the garage will be prepared promptly.

3.2 Conversion Schedule

The first bus (7930) was re-engined with a new engine and the prototype fittings from Hovey Associates. With approval of purchase of an extra engine, the original engine now becomes the spare. Bus #7926 is converted and 7928, 7927 and 7929 are in process, using the prefabricated interfacing components from Hovey Associates. The first conversions required 10 working days/bus; this is now reduced to 8. One bus/week is scheduled for completion of the series of 15 propane and one diesel bus. On-road operation of all 16 buses in the demonstration by mid-April is anticipated.

3.3 Fuel Tank Design

Concepts for tank shielding, fast fill and automatic fuel monitoring to 80% fill level are being explored, including design of a double fuel port tank and propane bus or fuel tank weighing as a means to monitor fuel levels.

3.4 Hovey Associates

The work by Hovey Associates on drawings of the fuel tank/engine interface were completed and a set of prototype parts was delivered. Hovey have been very cooperative and their worksmanship is excellent. They were awarded a contract to modify the remaining engine cradles at $1,200/bus.

3.5 Propane Fuel and Fuel Facility

The bulk fuel facility will be completed by the end of February. It will provide a fuelling rate of 50 gallons/minute and can be expanded at only modest added cost to fuel 60 buses. Superior Propane has done an excellent job and OC Transpo will check on the responsibility for initial inspection of the facility (Ministry of Consumer and Corporate Affairs) and tests for corrosion. A redesign of siting of the meter was required and resulted in an extension of the buried pipeline required at OC Transpo expense ($24,000). The remainder of fuelling station expense was accepted by Superior Propane.

3.6 Certification

16 of the 29 employees at OC Transpo who have passed the S6A are enrolled at Algonquin for the S6B course (inspection of in-vehicle fuelling systems). This will provide a total of 18 persons at OC Transpo with the combined installer-inspection certification.

Training on the fuelling operation is to be provided by Superior Propane.

3.7 Safety

A simplified and pocket-size safety manual is under preparation and will be completed before March 31.

The Ottawa Fire Department has expressed gratitude for OC Transpo's initiative in producing a safety booklet and alerting the department to the need for focus on the propane problem and the offer of an old bus for fire training (not taken up yet).

There appears to be some literature available from the U.S. and Canadian Propane Gas Associations on propane fire-fighting and a course is available in California. It was agreed that the consultant would prepare a short position paper outlining the state of knowledge and training requirements.

3.8 The UTDC Test Program

Inspection of the UTDC facility used for the comparative testing of the Dereco engines and the GM 6V71 bus engine showed that the unique-to-Canada programmable engine-drive train dynamometer with computerized data acquisition was operative, but is used in an otherwise primitive test environment. While the test work is behind schedule and to date insufficient for OC Transpo's use, it appears that the testing will be completed by 31 March 1985.

MTC personnel will review the program and means to improve UTDC capability at a meeting to be held February 12 at the UTDC test centre in Kingston.

3.9 Fuel Quality and Cost

Analysis of samples from Superior Propane and Mannion showed them to be above the minimum for the automotive fuel (HD-5 grade) specification. Routine fuel inspections are scheduled; they will be conducted by Superior and occasionally checked (by MTC or NRC).

The price of diesel fuel to OC Transpo has risen to a current level of 41.6¢/litre. The present contract price and propane bus fuel economy test shows a fuel cost saving of 26-27% for the propane bus over the current 2-stroke diesel bus. The EMR representative led a discussion of future fuel prices, which concluded that the diesel-propane price gap was likely to grow even wider with oil and gas price deregulation, and that the propane bus could show fuel cost savings, even if a provincial fuel tax were applied at the same ad valorem level as for gasoline or diesel fuel.

3.10 Engine Optimization

It was agreed to defer consideration of a test program to optimize fuel economy/performance of the propane engine and to concentrate on the cold start-cold runnning program. OC Transpo is reviewing an offer by Dereco to test and improve cold weather performance.

4. Quarterly Report

The 3rd Quarterly Report will be issued with these minutes.

5. Demonstration Program Data Acquisition

Messrs. Jenkins, Turner and Webb have developed the requirements for the data acquisition aspect of the demonstration program. A recommended program, contract and budget will be issued in February.

6. Project Budget and Cash Flow

Details of the cash flow and budget to 31 March 1985 are contained in Quarterly Report #3. It is anticipated that expenditures totalling $490,000 will be billed to the MTC account for FY 1984/5, bringing the Ontario/Federal CREDA joint expenditures to 31 March 1985 up to $806,000 (83% of the $975,000 budgeted).

The funding of the remainder of the demonstration program requires adjustments due to:

1. Termination of the CREDA program by the federal government effective 31 March 1985. It is planned to complete the demonstration with the federal funding portion provided from the ENERDEMO program. (A final report is required for the CREDA program, based on the quarterly reports issued).
2. The ENERDEMO program funding will be sought by a new proposal (Webb was instructed to prepare this with EMR, OC Transpo and the Ontario Ministries for review before the February 21 Steering Committee meeting). A new agreement will be struck with the same program management arrangements as currently used, but with OC Transpo responsible for separately billing MTC/Ontario Energy and EMR for their contributions.
3. The revised program will meet the previous targets of the demonstration and certain new requirements of the ENERDEMO program.
4. The revised program will be structured to continue the demonstration period to 31 December 1986 (or further) - extending

the data collection period.

7. Any Other Business

1. It was agreed that a new model (Classic) bus would be included in the noise and vibration tests scheduled for April 22 at LETE.
2. OC Transpo has offered technical assistance to the Hamilton Street Railway Company in their proposed program of testing CNG (compressed natural gas fuelled) buses which will initially utilize Dereco 4-stroke engines.

8. Next Meeting

The next meeting of the Steering Committee was set for 9.30 a.m., 21 February 1985 at OC Transpo.

6

MINUTES OF STEERING COMMITTEE MEETING
PROPANE DEMONSTRATION PROJECT
HELD AT OC TRANSPO 4 MARCH 1985

Present: J.A. Bonsall (OC Transpo) - Chairman
O. Colavincenzo (MTC)
K. Taylor (MTC)
J. Turner (MTC)
G. Olah (MOE)
J. Heenan (EMR, Transportation Energy Division)
P. Belzile (EMR, Enerdemo Office)
W.D. Jenkins (OCT) - Project Manager
R.F. Webb - Consultant

1. Minutes of Previous Meeting

Certain Steering Committee mmembers had not received the last minutes and were asked to transmit comments on the minutes to W.D. Jenkins. If no amendments are received the minutes are taken as adopted.

2. Review of Draft Proposal for Phase 2 of the Demonstration

The draft proposal was criticized on the following bases by MTC/MOE:

a. It contains items that extend the scope of the work beyond that originally set - the principal new item being the "engine optimization" budgeted at $130,000.

b. The extension of the demonstration into the first months of financial year 1986/7 poses difficulties for MOE.

c. The extensions contained in the draft proposal require unacceptable added expenditures (MOE/MTC). It was recognized that the support from EMR's Enerdemo program (in place of the CREDA mode of funding) necessitates redefinition of emphasis - particularly the requirement for information and technology transfer, including publicity.

The resolutions agreed were:

a. The work to optimize the engine for cold-start, emissions and fuel economy will not be included in the program. A small contract placed in FY 1984/5 will provide information on ways to improve the cold start, emissions and fuel consumption, but it was felt that the engine manufacturer had the incentive and obligation to undertake work in this area to develop the market for propane engines.

b. The development of an improved fuel monitoring/fuel control system was approved for inclusion in the demonstration on the basis of the priority assigned to safety and winter indoor garaging of the buses. The technologies available will be reviewed by the Project Manager and the Consultant to substantiate a proposal which will be reviewed by the Steering Committee).

c. The requirement for publicity, information, technology transfer was agreed. The level of technical consultant support for this activity ($30,000) will be substantiated/reviewed through Steering Committee review of a detailed proposal.

d. The total level of funding proposed for Phase 2 will therefore be $495,000 contributed as follows:

OC Transpo:	$225,000
MOE (through MTC):	135,000
EMR Enerdemo:	135,000

Revised proposals consistent with the above changes will be issued by March 11 by OC Transpo, which will lead to separate agreements being struck by OC Transpo with EMR Enerdemo and MTC (for MOE).

3. The Current Demonstration Program (Phase 1)

3.1 Budget

Expenditures chargeable to the CREDA program in FY 1984/5 will total $485,000-490,000. Requests are being prepared by OC Transpo to transfer certain of the budgeted funds among categories within the $485-490,000 total.

It is anticipated that expenses under the CREDA contract to its termination on 31 March 1985 will total about $804,000 with about $141,000 of the budgeted $943,940 project total unexpended at that time.

3.2 Completion of CREDA Funding Phase

The requirements to complete the CREDA-sponsored phase (Phase 1) of the demonstration include issue of quarterly report #4 and a final report. It was agreed that the final report should be in the form of an extended executive summary, together with an Appendix containing the technical reports, technical notes, minutes of Steering Committee meetings, and quarterly reports generated under the program. The executive summary (only) will be translated into French (via J. Hennan of EMR).

3.3 Quarterly Report #3

Comments/changes required are to be sent to the Project Manager by March 22.

3.4 Synergistics Ltd.

It was agreed that the minutes should note that the performance of Synergistics Ltd. under the publicity contract had been unsatisfactory and that the company would not be invited to bid on any future work in the demonstration.

3.5 Current Status

Considerable discussion was held on the failure of propane engine #7 after only 91 km and 3-4 hours of on-road service (and 20-25 hours of run-in at the supplier's plant). Mr. M. Signer, the propane project engineer of Dereco Ltd., described his preliminary findings and intent to issue a report on Dereco's investigation of the failed cylinder liner within 7 days. The engine has been repaired at OCT premises by Dereco personnel at no expense to the project or OCT under the terms of the one year engine warranty. The failure incident will be described in a forthcoming Project Technical Report (issue mid-April), with particular reference to the determination of whether the liner and subsequent engine failure was an isolated incident or whether the risk exists that more of the propane engines will fail from this cause in the future.

5 propane buses were in service on March 4: 8 are expected to be in service by March 31.

The 5 vehicles in operation have had no problems. The fuelling facility is not complete.

3.6 Technology Transfer Requirement

a. The CREDA final report will be made available to other properties by EMR after issue about March 31.

b. A summary of a paper on the demonstration is required by March 14 in anticipation of a June 1986 publication in Transportation Forum.

c. An "SAE standard" paper is to be prepared for the 1986 conference "Gaseous Fuels for Transportation." A summary is to be prepared by about March 31 and a draft issued to the Steering Committee members for their review and comments by mid-April 1985.

d. Two papers have been scheduled for presentation/publication at the June 1985 Highway Vehicle Systems Contractors' Coordination Meeting in Windsor, Ontario: one on the demonstration (OCT), the other on the engine technology (Dereco).

4. Next Meeting

The next meeting of the Steering Committee at OC Transpo is scheduled for 9.30 a.m. Friday, 10 May 1985.

APPENDIX E

CUTA PRESENTATIONS

MR. W.D. JENKINS
(EQUIPMENT DEPT., OC TRANSPO)

PRESENTATION - MEETING OF THE
CANADIAN URBAN TRANSIT ASSOCIATION

OTTAWA, ONT.
21 NOVEMBER 1984

NOTES FOR W.D. JENKINS

"FUEL ECONOMY OF CANADA'S CITY BUSES"

1. Introduction

At this point we can only report on the start-up of the demonstration program. The first few of our buses are now being converted to propane. The prototype engine and bus have been tested for compliance with the specifications we set the engine manufacturer, and after successful Go/No-Go acceptance tests, we have operated the first bus in revenue service without problems. It is a good beginning to the testing period that lies ahead.

2. Bus Conversions

The fitting of the 6-in-line converted 4-stroke engine from Dereco into the engine compartment of the "New Look" GM bus and interfacing with the Allison V-drive transmission involved a number of changes in the location and size of the cooling fan, in the exhaust system ducting, in the electrical ignition system, and in the mounting of the engine, but it now appears that we have an engine system that is almost as easy to replace and service as the GM 6V71 which can be handled routinely by the maintenance shop. This validates the decision made to retrofit the buses within the property rather than to contract out the job.

[SLIDE 1 - ENGINE IN CRADLE   SLIDE 2 - VIEW OF ENGINE IN BUS]

The design of the in-vehicle fuel storage system has also provided experience and few problems.

[SLIDES 3 & 4]

Our design contains 4 vessels manifolded to form one single fuel tank, which is filled from one side of the bus, at which point all the valves and gauges are within easy access. The tank is designed for maximum safety and incorporates shielding to minimize damage from manhole covers and rocks that may be encountered in service, and valves which automatically shut off propane flow to the engine if lines are severed, or vent propane to the air in the event that excess pressure builds up in the tank. We are working on improved tank designs to speed up the fuelling rate and to permit the bus to be fuelled from either side or both sides of the bus.

The major problems reported in our survey of operations on propane and our work on the propane safety manual are associated, not with operation of the vehicle, but with refuelling. We will avoid a frequently cited problem of fuel spillage and fuel hose rupture, which can occur when the bus is driven off while the fuel line is still connected, by incorporation of a valved quick-release system in the fuelling line. We plan to seek designs and to test a system which will weigh and control the propane delivered to the fuel tank assembly to avoid overfilling the tank. This becomes a problem when the bus is over-filled by mistake with cold propane, which may later expand and be vented while the bus is parked in the heated garage, creating unsafe conditions.

3. Initial Performance Test of the Propane Engine

3.1 Dynamometer Tests

OC Transpo uses an engine dynamometer test as a routine measure of the power output, and hence, condition of its engines. The Go/No-Go acceptance test for the first engine required that the propane engine achieve the same performance as the Detroit Diesel 6V71N equipped with C55 injectors.

[SLIDE 5]

Slide 5 shows that the prototype propane engine in a 1979 version of the GM "New Look" bus had a performance curve almost identical to that of a typical GM diesel in a 1982 bus. In fact, the acceleration from rest was somewhat better for the propane engine, reflecting the higher torque available from that engine at low speeds than the torque of comparable diesels. This "pick up and go" is noticeable in the bus and this is one of the reasons for the favourable comment we have received from drivers of the propane bus.

Our observations on the series production engines when under test at the manufacturer's plant were that dynamometer test results did not vary significantly from one engine to another, or from that of the prototype, and accordingly we expect consistent power output in the propane bus fleet. There are indications that the timing of the propane engine will need to be reset regularly to maintain optimum power and fuel economy, but we are now equipped to do this routinely. Further ways of optimizing the fuel economy and power output of the propane engine are expected to be available from work now being conducted for us by the Urban Transportation Development Corporation (UTDC) in Kingston.

3.2 Road Tests

The loaded prototype propane bus and an equivalent diesel bus were then operated over two typical routes to compare route times, average speed and the propane consumption.

[SLIDE 6]

As shown in Slide 6, one route was a typical city route with 80 official stops over the 10 mile circuit; 29 additional stops were made, due to pedestrians, traffic, and lights on the diesel circuit. On the propane circuit only 27 unscheduled stops were made. Adjusting for these, the diesel and propane buses had identical performance. The same was true for the suburban route which had 31 official stops over an 18 mile route which included a stretch of the Queensway. After adjustment for the difference in additional stops, the time and average speed of the propane and diesel buses were the same within the accuracy of the measurements.

A rough measurement of the propane consumption on these routes showed that the propane bus on the city circuit gave 2.34 miles per gallon of propane, the same bus on the suburban route gave 3.37 miles per gallon.

3.3 Go No-Go Tests

More accurate measurement of the fuel consumption of the propane bus compared to the diesel bus equivalent was required to meet the propane engine acceptance criteria set for the manufacturer. A Go/No-Go decision on continuation of the demonstration was to be made based upon the demonstration that the volume of propane consumed by the fully-loaded propane bus would be not greater than 1.8 times the volume of diesel fuel consumed by an average GM diesel bus, similarly loaded and operated over the same test circuit.

The tests were run at a local test track - the use of which was provided by the Department of National Defence - using a version of the Advance Design Bus (ADB) fuel economy test procedure adjusted for the 1.75 mile test circuit available. The ADB test procedure simulates a mix of city, arterial and commuter service by control of the number of stops, dwell time at each stop, acceleration, deceleration, cruise distance and top speed of an instrumented bus over 7 laps of the test circuit, with the distance measured by a fifth wheel.

[SLIDE 7] [SLIDE 8]

As shown in Slide 8, to our relief the volume of propane used by the propane bus was 1.7 times the diesel fuel consumption of the diesel bus over the same test circuit and well within the Go/No-Go limit of 1.8 of the engine specifications. The propane bus showed a fuel consumption of 3.1 miles per gallon (91.4 litres/100 kilometers); the diesel bus 5.26 miles per gallon (53.65 litres/100 kilometers) on the test track.

Based on experience of propane buses in service in Switzerland and expected technical improvements, we have set a propane-to-diesel fuel consumption target of 1.6 for the future.

3.4 Noise Tests

The change to propane fuel will not be dictated solely by the economics of fuel consumption. Our observations of propane buses in service confirm the view that the improved quality of the ride attained with the propane bus may be an important factor in gaining rider and driver acceptance. We are now involved in measuring these ride comfort factors and can report the measurements we have made on interior noise levels. As shown in the next slides

[SLIDE 9 and SLIDE 10]

the noise level inside the propane bus is much lower than in the diesel equivalent, both when the bus is in motion and stationary. It should be borne in mind that the curves illustrating the difference in noise levels in decibels are on a logarithmic scale. One decibel level is a significant change in noise level. In practice in the propane bus the interior noise level is low enough to encourage conversation in the bus. The low interior noise level has shown up other sources of noise, such as rattling windows, which have been fixed. In the diesel bus these low level sources of noise are less obvious.

We have some preliminary data on drive-by noise which has been used to guide the design of the exhaust system, but this needs validating before publication.

4. Overall Impression

In summary, the test results to date are encouraging, as is the driver response. The public has not yet noticed or commented on the first propane bus in service. We look forward to obtaining sufficient data from the remaining tests and demonstration period to enable us to evaluate the economics and system compatibility of the propane fleet.

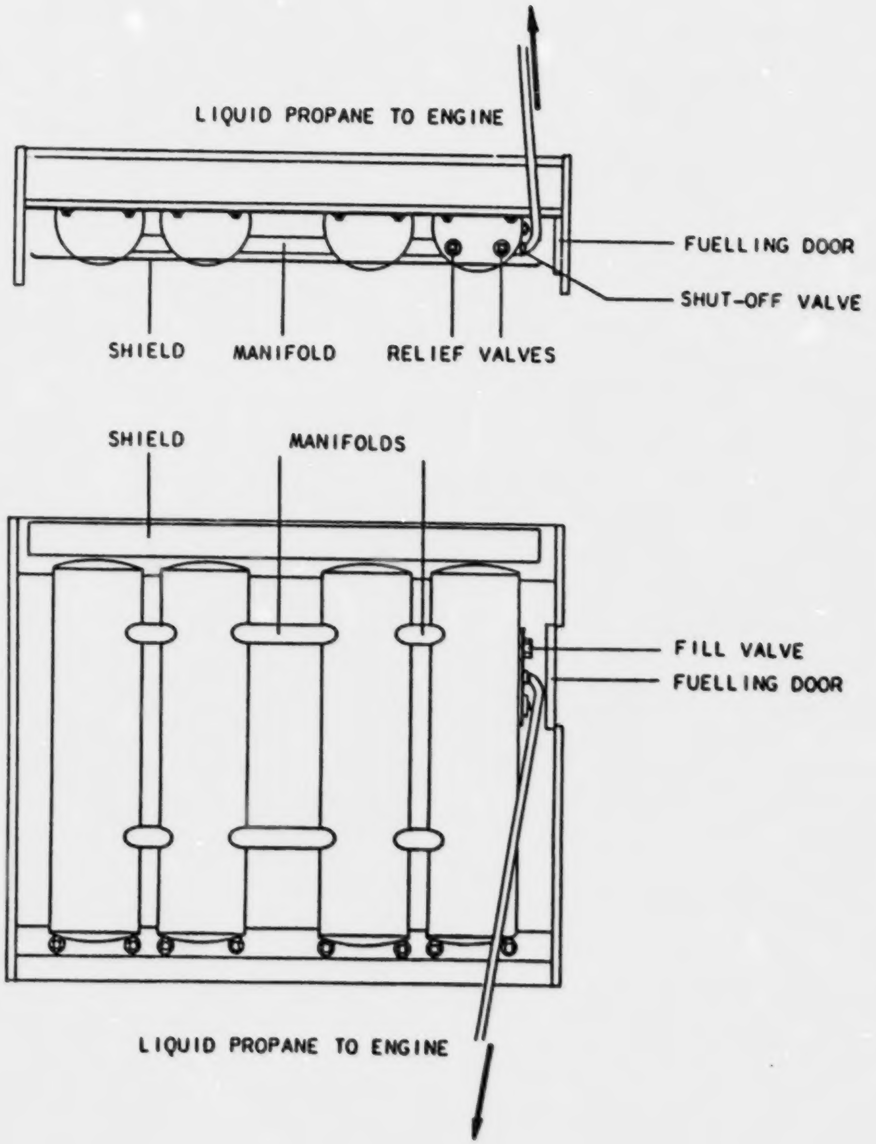
ENGINE IN CRADLE

#2

ENGINE IN BUS

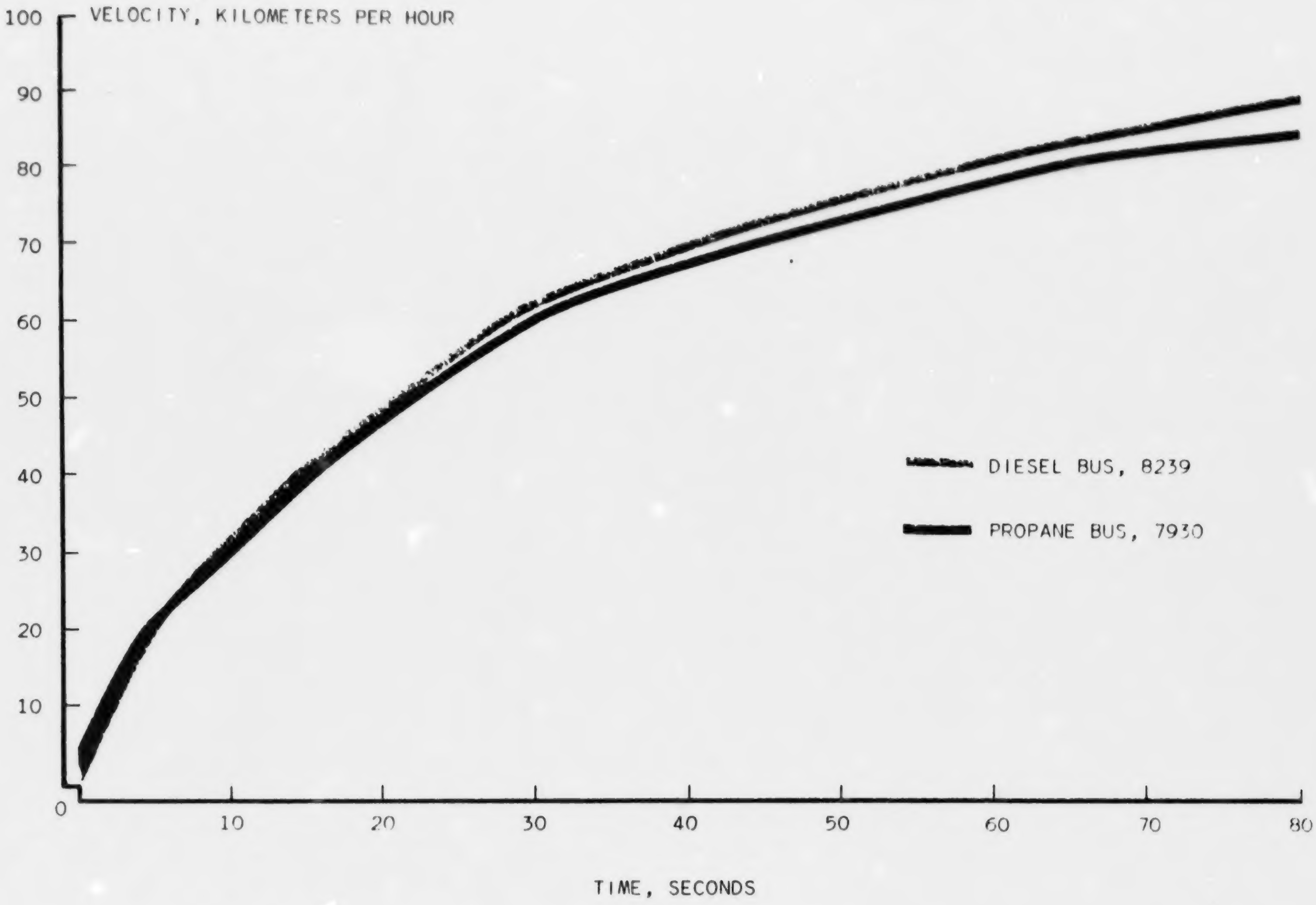
FUEL TANK

THE BUS FUEL TANK SYSTEM


LIQUID PROPANE TO ENGINE
FUELLING DOOR
SHUT-OFF VALVE
SHIELD
MANIFOLD
RELIEF VALVES
SHIELD
MANIFOLDS
FILL VALVE
FUELLING DOOR
LIQUID PROPANE TO ENGINE

#4

COMPARISON OF ACCELERATION OF PROPANE AND DIESEL BUS



#5

ROAD TEST: PROPANE AND DIESEL BUSES

	CITY ROUTE #1		SUBURBAN ROUTE #99	
	DIESEL	PROPANE	DIESEL	PROPANE
OFFICIAL STOPS (10 SEC.)				
NUMBER	80	80	31	31
TIME	13 MIN. 20 SEC.	13 MIN. 20 SEC.	5 MIN. 10 SEC.	5 MIN. 10 SEC.
ADDITIONAL STOPS				
NUMBER	29	27	25	24
TIME	7 MIN. 8 SEC.	6 MIN. 35 SEC.	5 MIN. 3 SEC.	4 MIN. 50 SEC.
TOTAL TIME	62 MIN. 20 SEC.	61 MIN. 57 SEC.	51 MIN. 36 SEC.	51 MIN. 17 SEC.
MEASURED LENGTH OF ROUTE	15.5 KM	15.9 KM	29.2 KM	29.8 KM
AVERAGE SPEED	22.21 KM/HR	23.04 KM/HR	42.3 KM/HR	43.3 KM/HR

FIFTH WHEEL

FUEL CONSUMPTION COMPARISON
PROPANE AND DIESEL BUS (MARCH 1984)

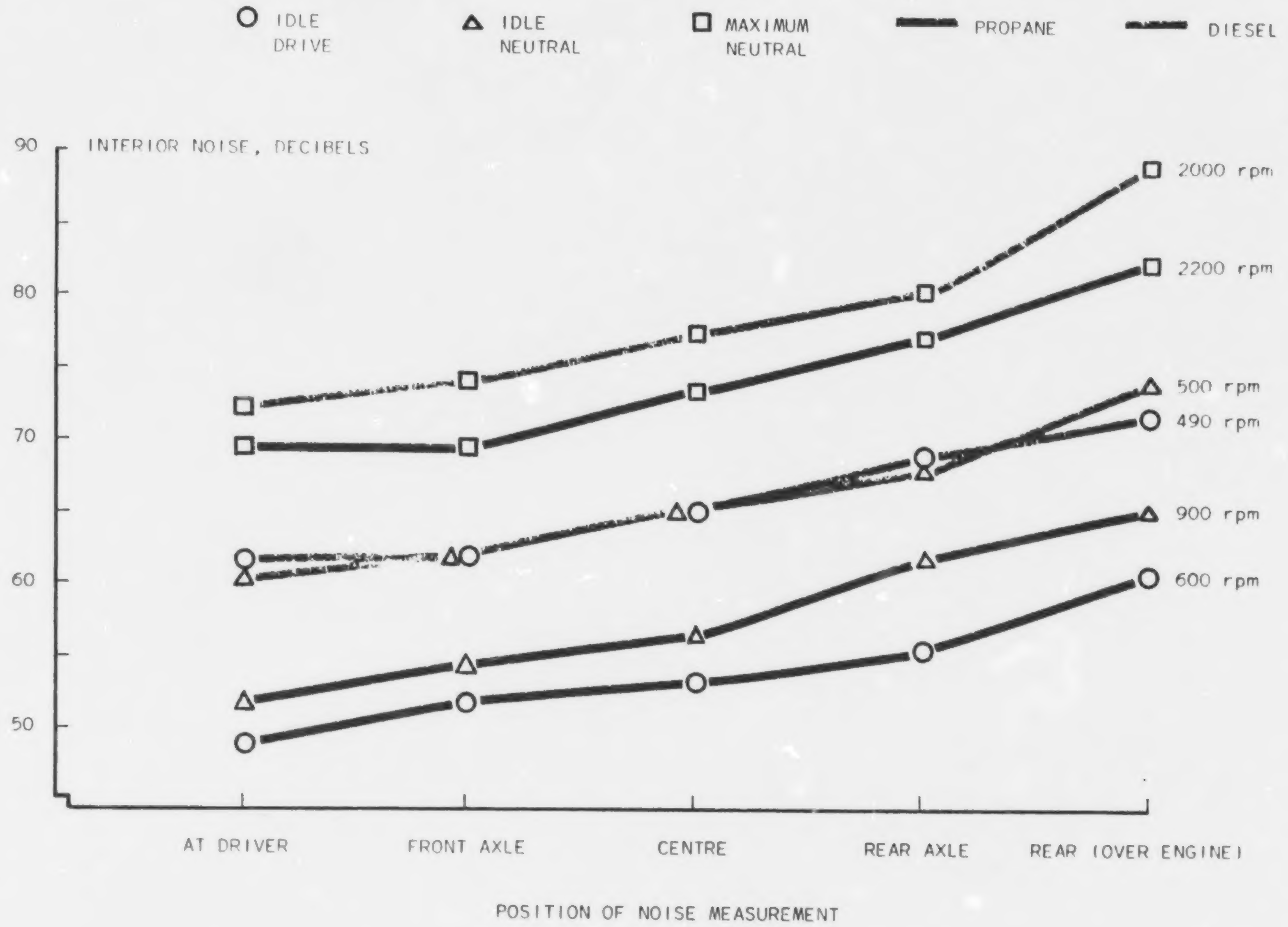
7 LAPS OF 1.747 MILES: TOTAL 12.23 MILES IN ADB-CYCLE TEST

	DIESEL	PROPANE
CONSUMPTION, POUNDS	18.6-19.6	20.0-20.6
AVERAGE CONSUMPTION, POUNDS	19.08	20.22
AVERAGE CONSUMPTION, IMP. GALS.	3.965	2.33
FUEL ECONOMY, MPG	5.256	3.965
LITRES/100 km.	53.65	91.4

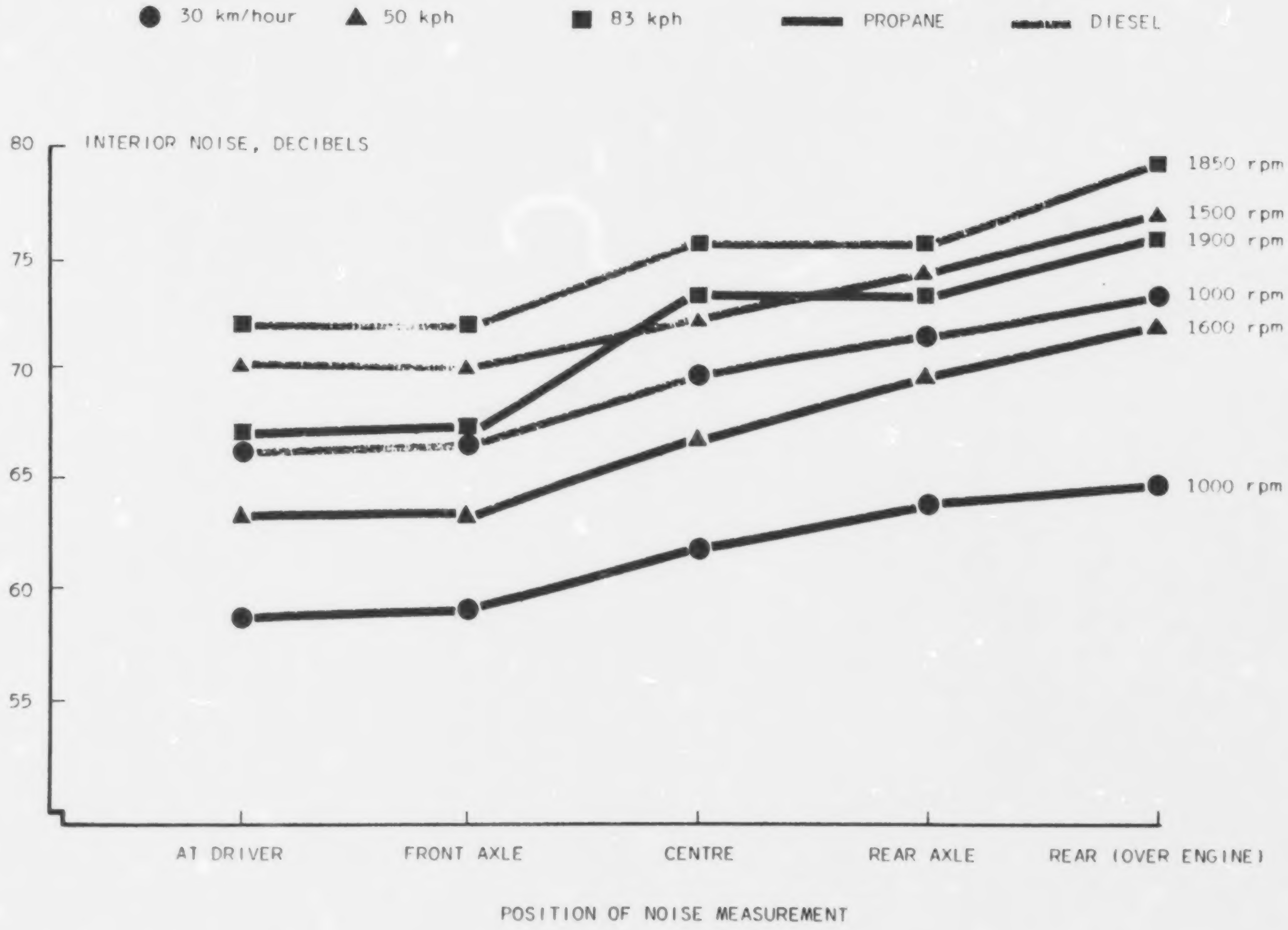
RATIO PROPANE TO DIESEL VOLUME 1.7

GO/NO-GO TEST REQUIREMENT NOT GREATER THAN 1.8

INTERIOR NOISE MEASUREMENTS - STATIONARY PROPANE AND DIESEL BUS



INTERIOR NOISE MEASUREMENTS - CONSTANT SPEED PROPANE AND DIESEL BUS

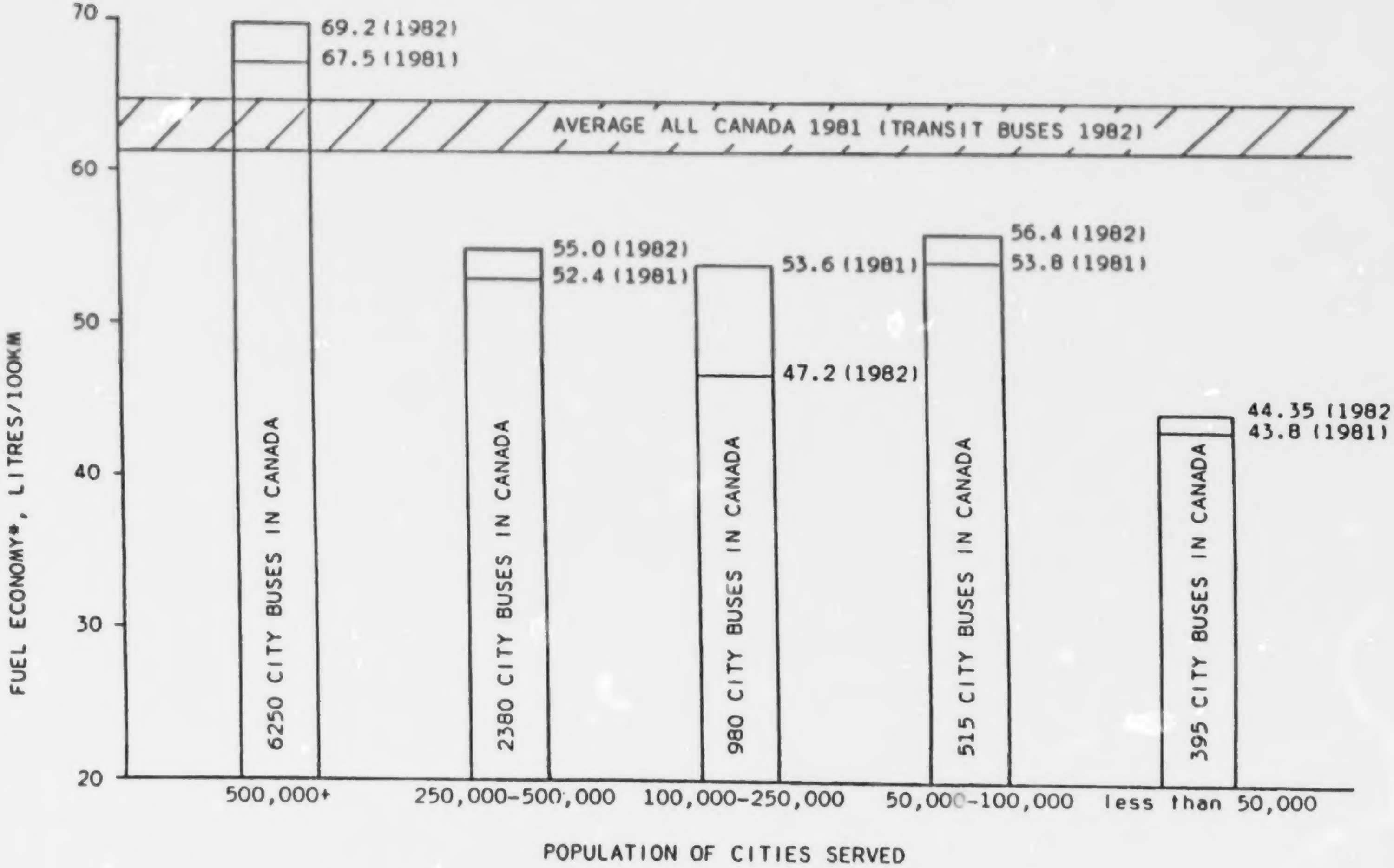


DR. R.F. WEBB
(R.F. WEBB CORP. LTD.)

PRESENTATION - MEETING OF THE CANADIAN URBAN TRANSIT ASSOCIATION

OTTAWA, ONT.
21 NOVEMBER 1984

FUEL ECONOMY OF CANADA'S CITY BUSES



Data from 1983 report by Canadian Urban Transit Assn., "Operating Characteristics of Member Systems," (1981-1982)

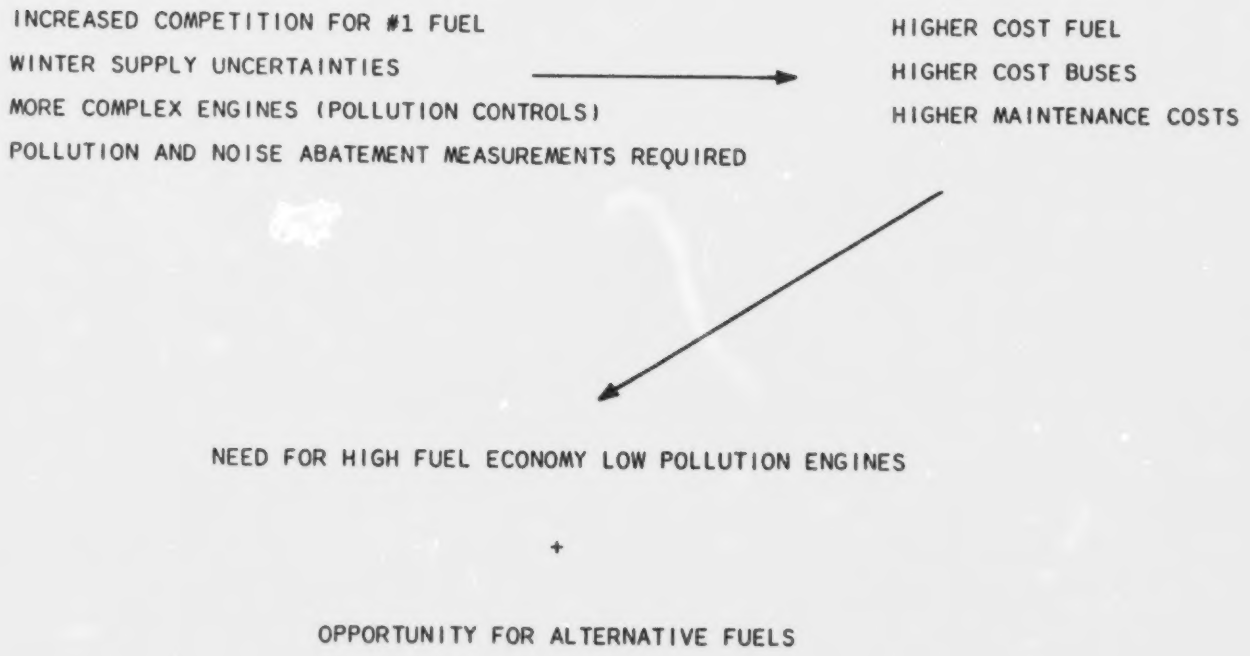
*1982: Total diesel 331.83 million litres; total gasoline 3.735 million litres; in 10,560 active buses.

1981: Total diesel 328.3 million litres; total gasoline 2.82 million litres; in 10,394 active buses.

BUS DIESEL FUEL PROBLEMS IN SUMMARY

SUPPLY/DEMAND	CRUDE OIL ISSUES:	- INSUFFICIENT DOMESTIC PRODUCTION
		- UNRELIABLE IMPORTS
	REFINERY ISSUES:	- LIMITED DIESEL PRODUCTION FROM EACH BBL CRUDE OIL
		- DIESEL DEMAND OUTSTRIPS REFINERY CAPACITY
		- SLOW GASOLINE GROWTH AFFECTS DIESEL PRODUCTION
	MARKET ISSUES:	- FAST GROWTH OF DIESEL AND AIRCRAFT KEROSENE USE
QUALITY	CRUDE OIL ISSUES:	- DETERIORATION OF CRUDE QUALITY HAS HEAVY IMPACT ON DIESEL
		- LIMITED #1 QUALITY FUEL AVAILABLE
		- DIESEL SUPPLIES STRETCHED BY QUALITY REDUCTION
POLLUTION CONTROL	FUEL ISSUES:	- INCREASES COMMERCIAL DEMAND FOR DIESEL
		- INCREASES DEMAND FOR #1 DIESEL
	ENGINE ISSUES:	- HIGH COST FOR NOx AND PARTICULATE CONTROL
		- INCREASE IN FUEL CONSUMPTION LIKELY
		- INCREASES ENGINE COMPLEXITY AND SERVICE
		- POOR PROSPECTS FOR 2-STROKE ENGINE
		- NOISE LEGISLATION IS NEXT ON AGENDA
FUEL PRICE		- TEN FOLD INCREASE 1973 TO 1984
		- FUTURE INCREASES HIGHER THAN INFLATION

FUTURE OUTCOME FOR CITY BUS PROPERTIES



INCREASED COMPETITION FOR #1 FUEL
WINTER SUPPLY UNCERTAINTIES
MORE COMPLEX ENGINES (POLLUTION CONTROLS)
POLLUTION AND NOISE ABATEMENT MEASUREMENTS REQUIRED

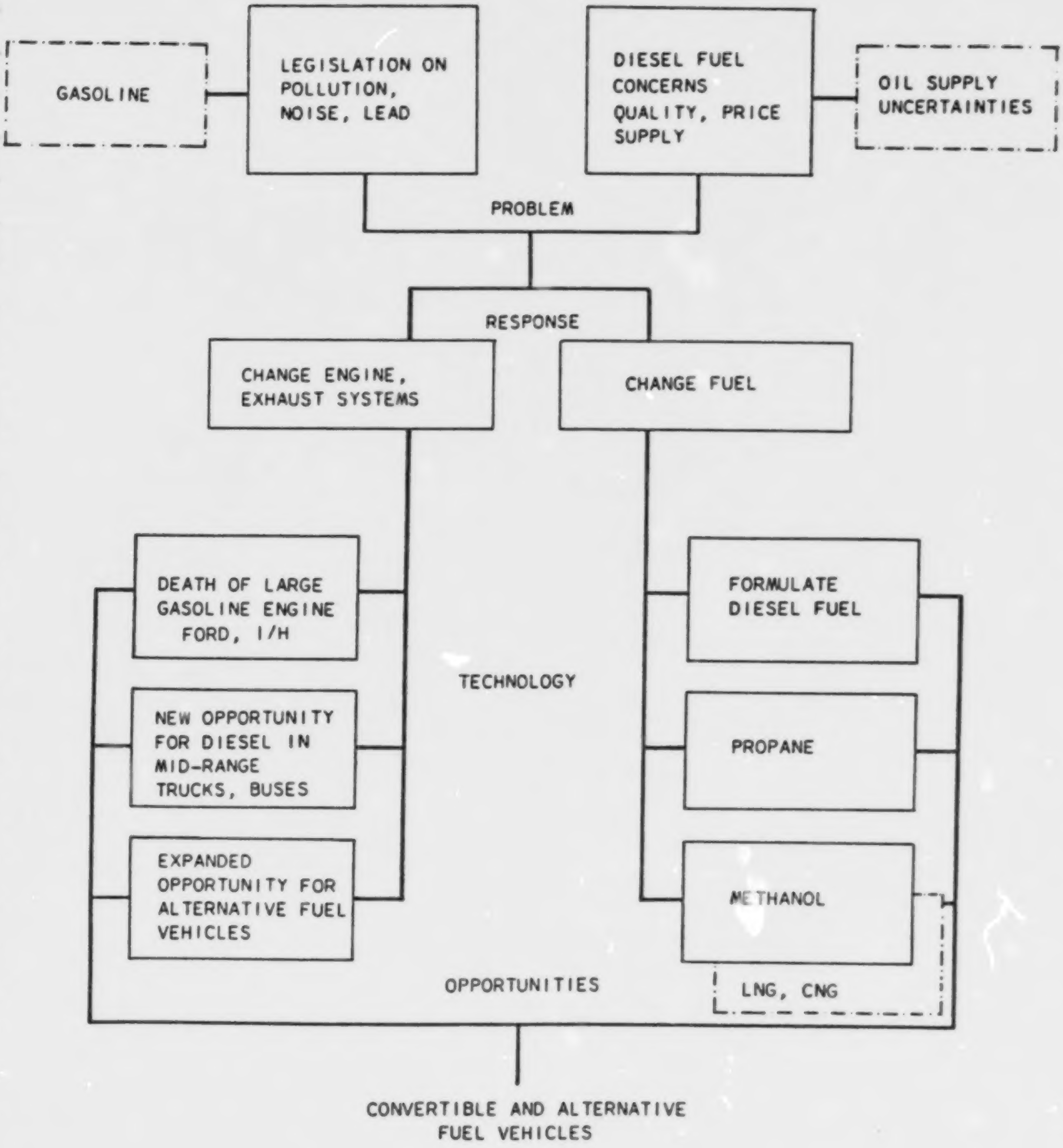
HIGHER COST FUEL
HIGHER COST BUSES
HIGHER MAINTENANCE COSTS

NEED FOR HIGH FUEL ECONOMY LOW POLLUTION ENGINES

+

OPPORTUNITY FOR ALTERNATIVE FUELS

RATIONALE FOR ALTERNATIVE FUELS


GASOLINE
LEGISLATION ON POLLUTION, NOISE, LEAD
DIESEL FUEL CONCERNS QUALITY, PRICE SUPPLY
OIL SUPPLY UNCERTAINTIES
PROBLEM
RESPONSE
CHANGE ENGINE, EXHAUST SYSTEMS
CHANGE FUEL
DEATH OF LARGE GASOLINE ENGINE FORD, I/H
NEW OPPORTUNITY FOR DIESEL IN MID-RANGE TRUCKS, BUSES
EXPANDED OPPORTUNITY FOR ALTERNATIVE FUEL VEHICLES
TECHNOLOGY
FORMULATE DIESEL FUEL
PROPANE
METHANOL
LNG, CNG
OPPORTUNITIES
CONVERTIBLE AND ALTERNATIVE FUEL VEHICLES

THE OIL SUPPLY/DEMAND

	1984	1990	1995	2000
DIESEL DEMAND m3×1000/DAY	39	47	50	53
CANADA'S IMPORT REQUIREMENT MINIMUM m3x1000/DAY	35	26	29	32
COST OF IMPORTS MILLIONS $'s (1984)/DAY*	8.1	5.17	6.1	9.5
ANNUAL OIL IMPORT BILL BILLIONS $'s (1984)/YEAR	3.0	2.1	2.8	3.5
DIESEL % TRANSPORT FUEL	16	-	-	24-26%

* OIL PRICE FORECASTS (1984 DOLLARS)

1984: $231.40/m3 CIF
1990: 219.33
2000: 297.70

OIL AND PROPANE SUPPLY/DEMAND

(all in 1000 m3/day)

	1984	1990	1995	2000
OIL IMPORTS NEEDED	35	26	29	32
PROPANE SURPLUS TO CANADA'S NEEDS	7.5	6.3	5.4	4.3
DIESEL FUEL EQUIVALENT OF CANADA'S PROPANE SUPPLY	11.7	15.9	13.8	11.6
DIESEL FUEL EQUIVALENT OF PROPANE SURPLUS	4.7	3.9	3.4	2.7
TOTAL DIESEL DEMAND	39	47	50	53
CITY BUS DEMAND FOR DIESEL	0.91	0.92	0.94	0.94

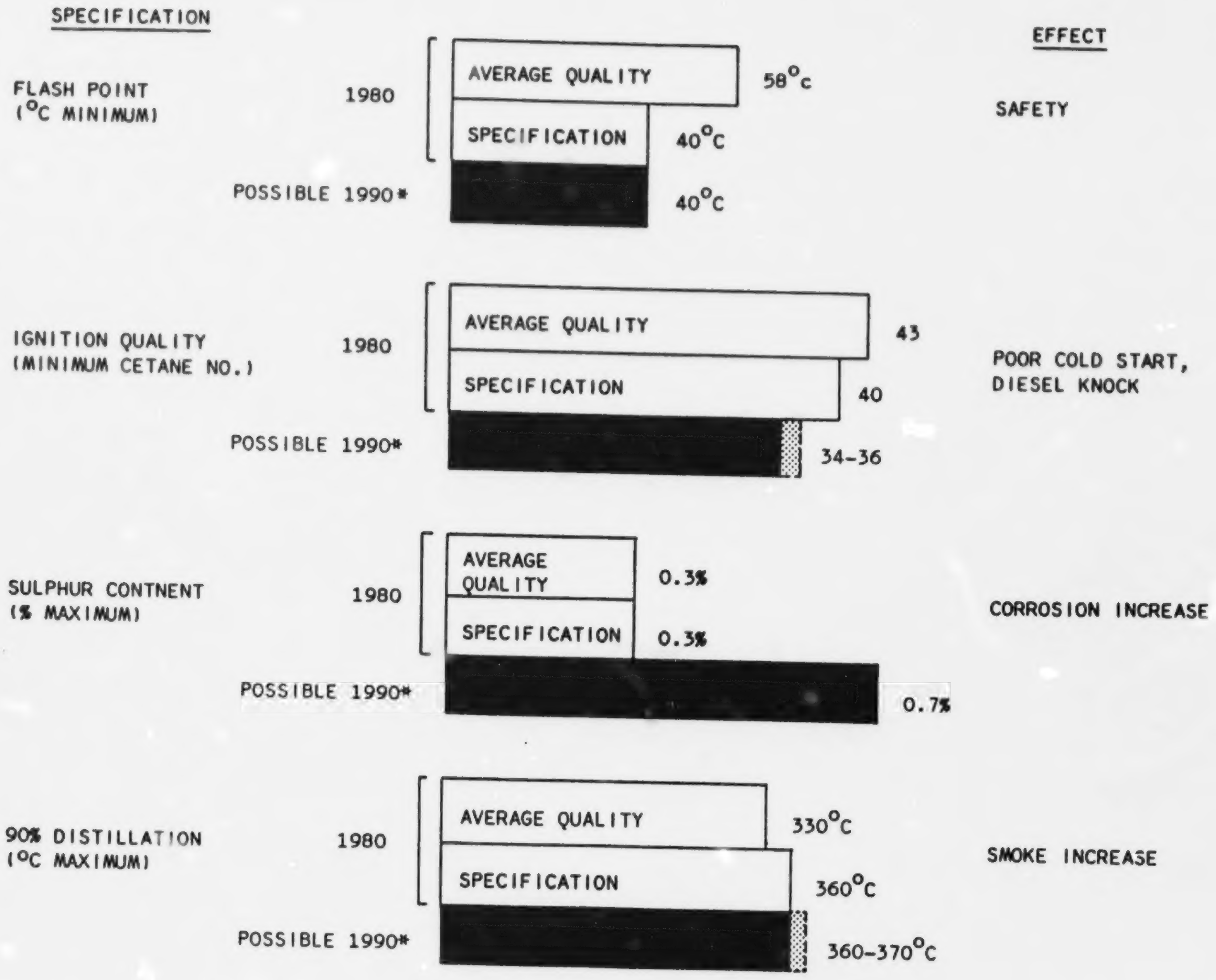
CONCLUSIONS:
1. PLENTY OF SURPLUS PROPANE FOR BUS & TRUCK CONVERSIONS
2. GAS EVEN MORE SO

THE REFINERS' PROBLEMS REGARDING DIESEL FUEL

(1000 m3xday)

		1984	2000	CHANGE
1.	DEMAND	39	53	+36%
2.	GASOLINE/DISTILLATE RATIO	1.2	1.01	-12%
3.	DIESEL QUALITY: CETANE # MINIMUM	40	36-37	-10%
4.	COST OF MANUFACTURE (1984 DOLARS) (28% IS OIL INCREASE)	INCREASES		+35%

DIESEL FUEL SPECIFICATIONS AND 1980 AVERAGE QUALITY



NOTE: * POSSIBLE 1990 = FUEL GRADE UNDER TEST BY CGSB TO SET 1990 STANDARDS.

CURRENT AND TENTATIVE SPECIFICATIONS FROM CSGB. 1980 QUALITY DATA FROM GULF OIL.

FUTURE POLLUTION LEGISLATION

(Grams of Pollutant/Brake HP)

	HYDROCARBON	NOx	CO	SMOKE (% opacity)*
CANADA CURRENT STANDARDS				
(Diesel and Gasoline Heavy Duty Vehicle)	combined 16		40	20/15/50
U.S. FEDERAL 1985**				
(Diesel Engines)	1.3	10.7	15.5	20/15/50
CALIFORNIA 1984+				
(Diesel Engines)	0.5	4	25	
OC TRANSPO'S PROPANE				
NOW	0.78	12.0	1.7	
FUTURE	0.75	9.3	1.8	

NOISE IS NEXT LEGISLATIVE TARGET

* At acceleration, lug and peak power

** U.S. 1987 proposal NOx 6.0 particulates 0.6g
1990 proposal NOx 4.0 particulates 0.25g.

PROPANE CONVERSION BENEFITS

- AUGMENTATION OF DIESEL SUPPLY BY SURPLUS PRODUCT
- COST OF PROPANE CAN BE LOWER THAN DIESEL WITH TAX INCENTIVES
- IMPROVED QUALITY OF RIDE - NOISE
  - VIBRATION
  - PULL AWAY FROM STOPS
- LOWER LEVELS OF POLLUTION
  AND POLLUTION CONTROL TECHNOLOGY IS SIMPLE

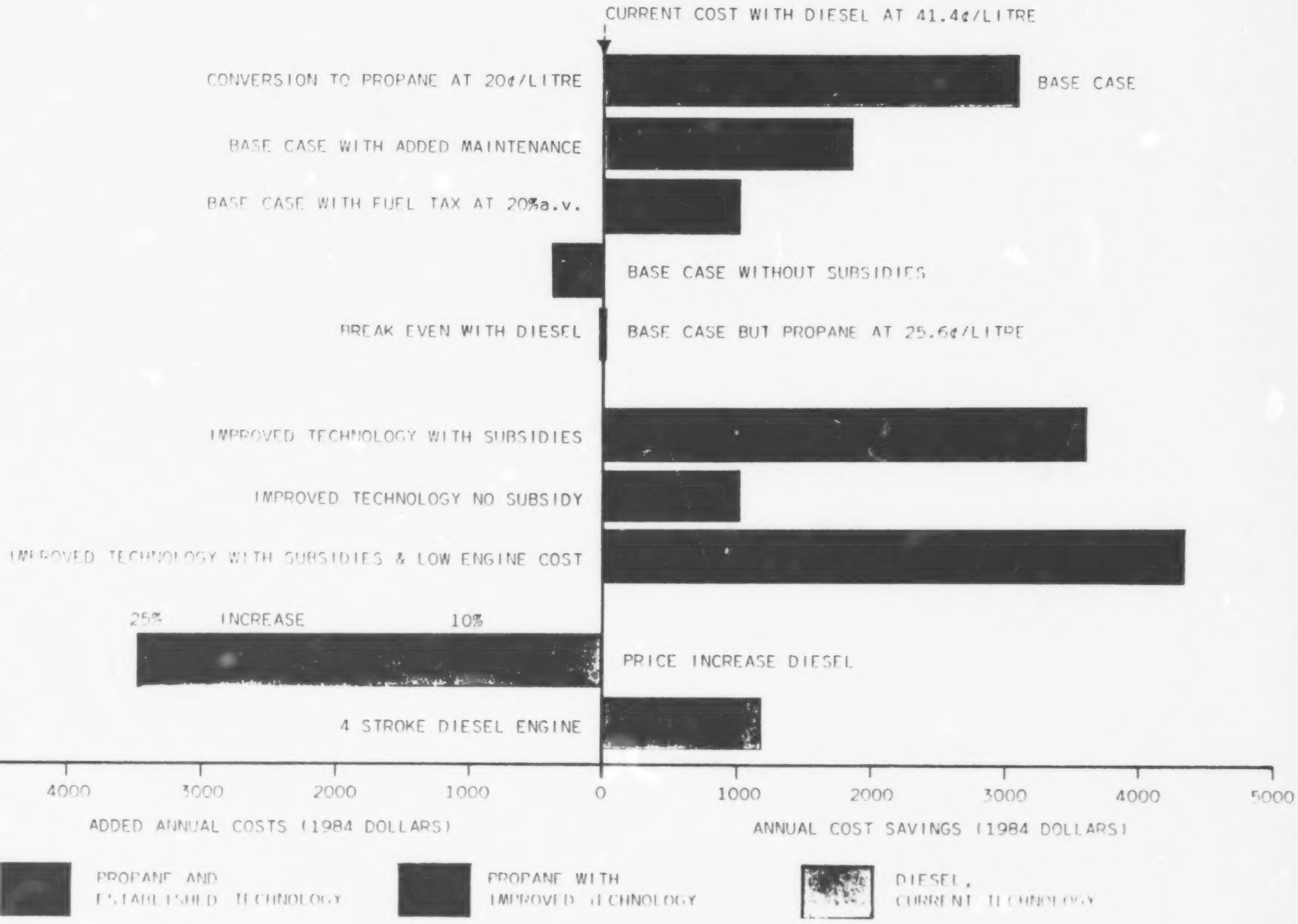
LIFE-CYCLE COSTS PROPANE, DIESEL, LNG

ONTARIO EXAMPLE

	DIESEL	PROPANE	LNG
FUEL COST AT PUMP ¢/LITRE*	41.64	22.06	19.65
BUS CONVERSION PREMIUM $	BASE	2,900	9,800
AFTER TAX CONVERSION COST (SAVING)	BASE	(9,050)	2,750
ANNUAL FUEL COST $	13,526	12,194	11,980
VARIABLE COST/ANNUM	68,421	67,089	66,875
FIXED COST/ANNUM	27,795	27,141	27,633
TOTAL COST/ANNUM	96,216	94,230	94,508
ANNUAL SAVINGS OVER DIESEL	–	1,986	1,708
SAVINGS WITH PROPANE AT 20¢/litre	–	3,092	–

* DIESEL TAXED, PROPANE & LNG UNTAXED,
BUT COSTS OF FUELLING FACILITY INCLUDED

CHANGES IN ANNUAL COST WITH PROPANE AND DIESEL BUSES



CRITICAL FACTORS FOR CONVERSION ECONOMICS

1. CONTINUED REMISSION OF SALES TAX ON VEHICLE
2. CONTINUED REMISSION OF FUEL TAX
3. NO LARGE INCREASE IN MAINTENANCE COSTS FOR PROPANE
4. CONTINUED COMPETITIVE PRICING OF PROPANE
5. IMPROVEMENTS IN FUEL CONSUMPTION TOWARDS THEORETICAL PROPANE TO DIESEL VOLUME 1:1.5
6. REDUCED COST OF PROPANE ENGINE AND PROPANE TANKS
7. LOW FUEL STORAGE AND REFUELLING COSTS
8. RETENTION OF RIDERSHIP THROUGH RIDE QUALITY IMPROVEMENT WITH PROPANE

MR. P.J. NEWGARD
(EQUIPMENT MANAGER, OC TRANSPO)

PRESENTATION - MEETING OF THE CANADIAN URBAN TRANSIT ASSOCIATION

OTTAWA, ONT.
21 NOVEMBER 1984

NOTES FOR PETER NEWGARD

"ORGANIZATION OF THE OC TRANSPO PROPANE DEMONSTRATION"

1. Introduction

Early in 1982 a decision to investigate propane use in city buses was made by OC Transpo based upon:

- reports of successful operation of current bus fleets in Vienna and Amsterdam and of past activities (1950's and 1960's) at Chicago Transit and San Jose Transit in California and
- OC Transpo's evaluation of alternatives to diesel fuel (CNG, LNG, propane, and methanol).

Encouragement was received from the federal department of Energy, Mines and Resources through funding of an initial investigation, and possibility of joint funding by the Ontario and federal governments of a large-scale propane demonstration under the fund-sharing provision of the CREDA (Conversation and Renewable Energy Demonstration Act) component of the National Energy Program.

The initial investigation provided first-run economics indicating cost savings for propane conversion, and an opportunity to visit companies active in the development of propane bus operations, such as Amsterdam Transit, the Dutch Road Research Laboratory and engine developers and manufacturers, such as M.A.N. in Germany and Dereco in Switzerland. The foreign visits were essential as no manufacturers of bus engines in N. America had commercial experience in the production of heavy duty, high-compression propane engines based on conversions of diesel engines, but were experimenting with these conversions. There was substantial N. American experience on the conversion of gasoline engines to propane, but the conversion of heavy duty gasoline engines was rejected as an option from past experience, which indicated high fuel consumption and high maintenance costs.

2. The Propane Demonstration Program

The propane demonstration is funded by OC Transpo, EMR and the Ontario Ministry of Energy, with each organization having specific but complementary specific objectives.

For OC Transpo the main objectives were:

- to gain information on the costs, operability, safety and compatibility of the propane fleet to facilitate the Commission's future decisions on vehicle and fuel acquisitions
- the objectives of the governments involved were principally aimed at reducing the Ontario and Canadian dependence on imported oil, the utilization of a Canadian surplus resource - propane, and the conduct of a demonstration which would provide data and visibility for their propane initiatives.

To reflect and co-ordinate the different approaches and requirements, we established the demonstration program with the energy ministries and the Ontario Ministry of Transportation and Communications and a Steering Committee to guide the program, while OC Transpo retains full responsibility for the acquisition and operation of the new bus fleet.

[STEERING COMMITTEE STRUCTURE SLIDE 1]

3. Engine Acquisition

All North American manufacturers of heavy duty highway diesels, and selected European companies with diesel/propane experience were invited to bid on supply of one propane engine for a Go/No-Go demonstration to be followed, if successful, by purchase of 14 more engines and services to assist OC Transpo in the re-engining of the 15 bus fleet and training for the retrofit and service. No North American supplier was interested at that time, and we placed the contract with a Swiss company, Dereco, which has pioneered propane conversion in heavy duty engines and supplied buses to Swiss transit systems. They chose to convert diesel engines supplied by FIAT's Iveco division, since these engines met the specifications we had set, which required a close match of the power, acceleration and easy serviceability and engine interchangeability we now enjoy with the GM 6V71 engines.

The main problems all manufacturers have with the replacement program is the small size of the engine compartment and the rotation direction of the engine: the GM 2-stroke has a unique clockwise rotation (when facing the engine) and other manufacturers must modify their engines to provide this sense of rotation if the Allison transmission is to be retained.

We paid a modest premium for the first engines, but understand that in series production the propane engine may be cheaper than the diesel, since the high cost injection system is replaced by a lower cost carburetion and spark-ignition system. This saving may offset the $2000 or so cost of the 800 litres of propane storage tank assembly required to provide the range we need.

The storage tank assembly has been designed and manufactured specially for the "New Look" city bus by Westeel Corporation to provide easy installation, rapid fill and maximum safety during filling and in service.

After the Go/No-Go tests with the first engine, we placed a contract with a local company to design the total interface and piping system so that the propane engine, like the current diesel, can be cradle-mounted and rapidly exchanged for service.

4. Fuel Supply

Although OC Transpo purchases propane for use in propane service vehicles, the fuel volume is small compared to that needed for buses, and the operation is conducted at a small garage site, not at the main bus garage located on St. Laurent Boulevard. Our requests for bids for propane supplies therefore included not only a price quotation, but also a requirement that the supplier provide assistance with the choice and installation of the bulk fuel tanks and refuelling station and with the process of obtaining local and provincial government approvals for the installation.

We were delighted by the price response and help received from the suppliers. Our price for propane is well within the range required to compete with diesel fuel where we need a price per litre lower than 60% of that for diesel fuel and our fuel storage and pump installation is in place with all required safety approvals.

5. Safety

One of the major problems with propane is the perception of safety. We have examined the 400-plus bus operation in Vienna in great detail from this point of view and have now completed a reference manual on propane safety which will be used to guide our installations, operations and the training of the staff responsible for fuelling, engine conversions and maintenance, for inspecting, garaging and operating the propane fleet. Our thanks are due to Transport Canada for assistance in the preparation of the safety manual. All steps necessary to maximize safety have been taken.

[AN OUTLINE OF THE FACTORS INVOLVED IN ESTABLISHING THE SAFETY SYSTEM IS GIVEN IN SLIDE 2]

6. Staff Training

We have completed the training and certification of the staff responsible for the installation of the propane systems in the fleet: 29 out of 30 tested have been awarded S6A certification and we plan to have others trained and certified for both the installation and inspection of propane buses and for the refuelling process.

The drivers are also to be given instruction on the steps necessary in the event of accidents or propane leaks, but the Go/No-Go test and driver experience with the prototype propane bus indicate no driver retraining is required.

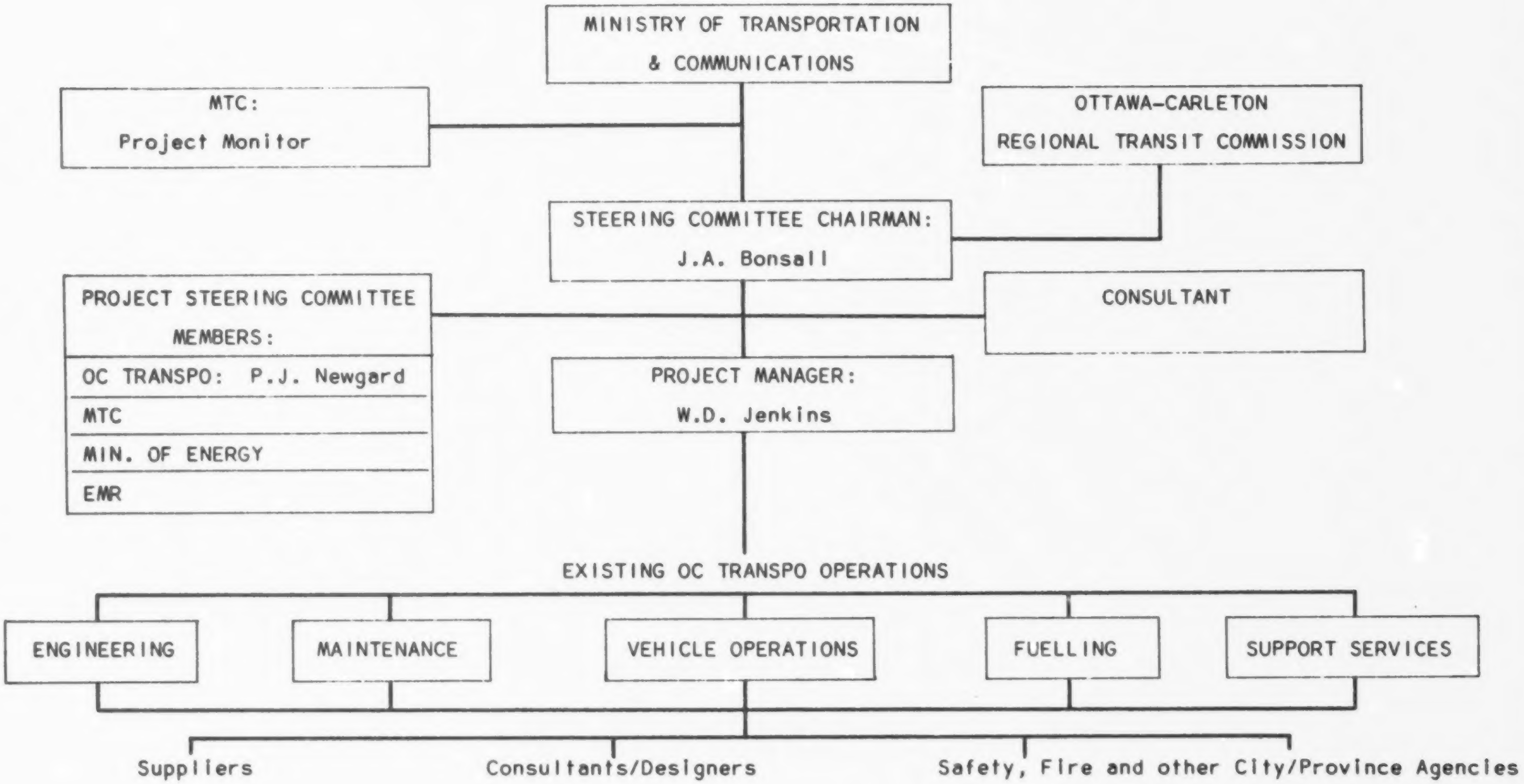
7. Future Work

[SLIDE 3]

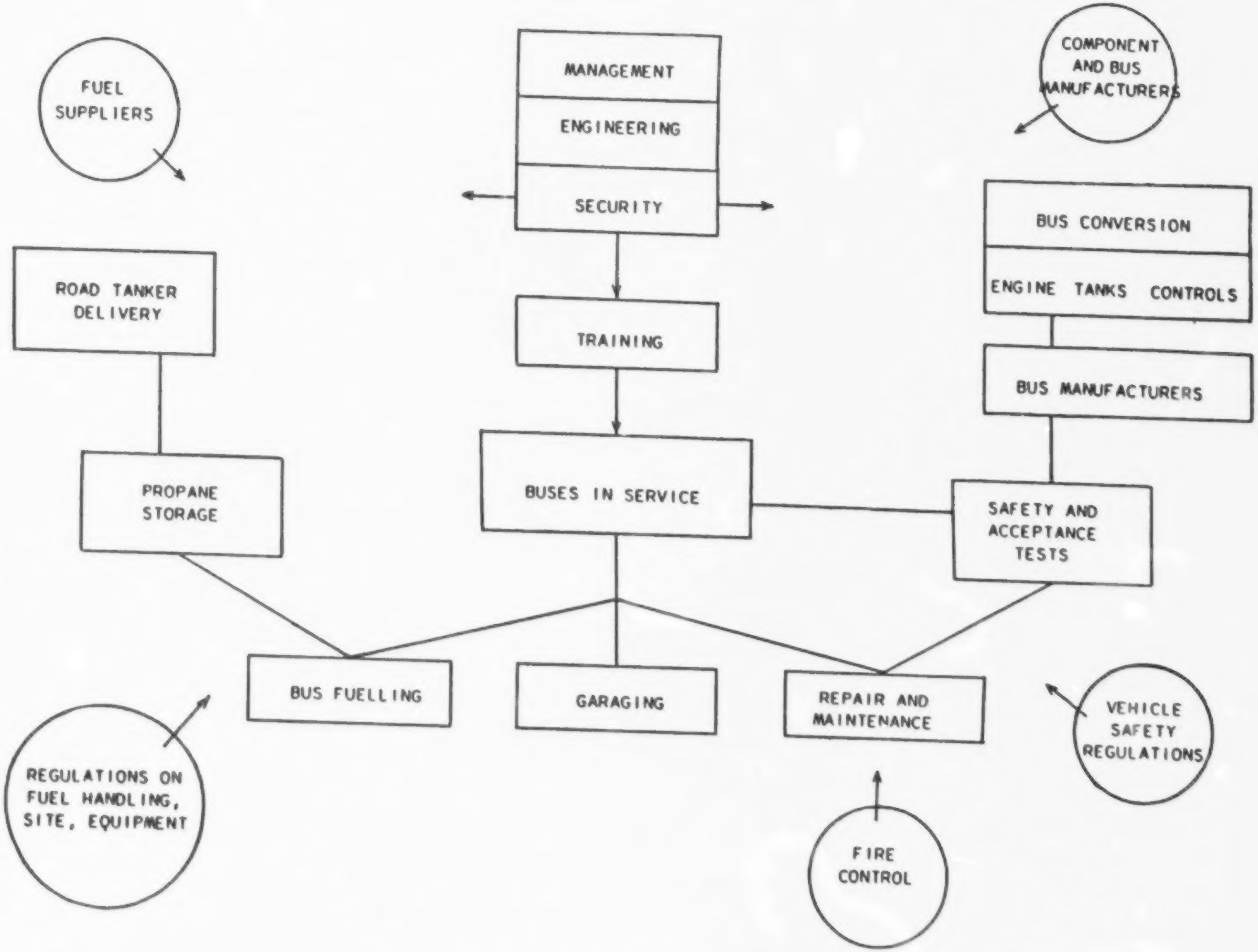
Slide 3 summarizes the schedule for the conversion and demonstration program. As we now see it, the 15 propane buses will all be in service before the New Year and we are likely to operate the fleet until August 1986 when decisions are to be made on the continued operation of the 15 buses in revenue service, or whether to convert them back to diesel fuel operation, or depending upon the safety, operational performance and demonstrated costs whether to recommend wider use of propane as a bus fuel in the future.

As the schedule shows, we plan to audit operations on propane, to inspect the converted vehicles at regular intervals and to conduct passenger and driver surveys. interim technical and progress reports are being issued, and the total program will be reported and assessed by September 1985. We are encouraged by the performance to date, which will now be reported by the Manager of the Demonstration Project, Mr. Bill Jenkins.

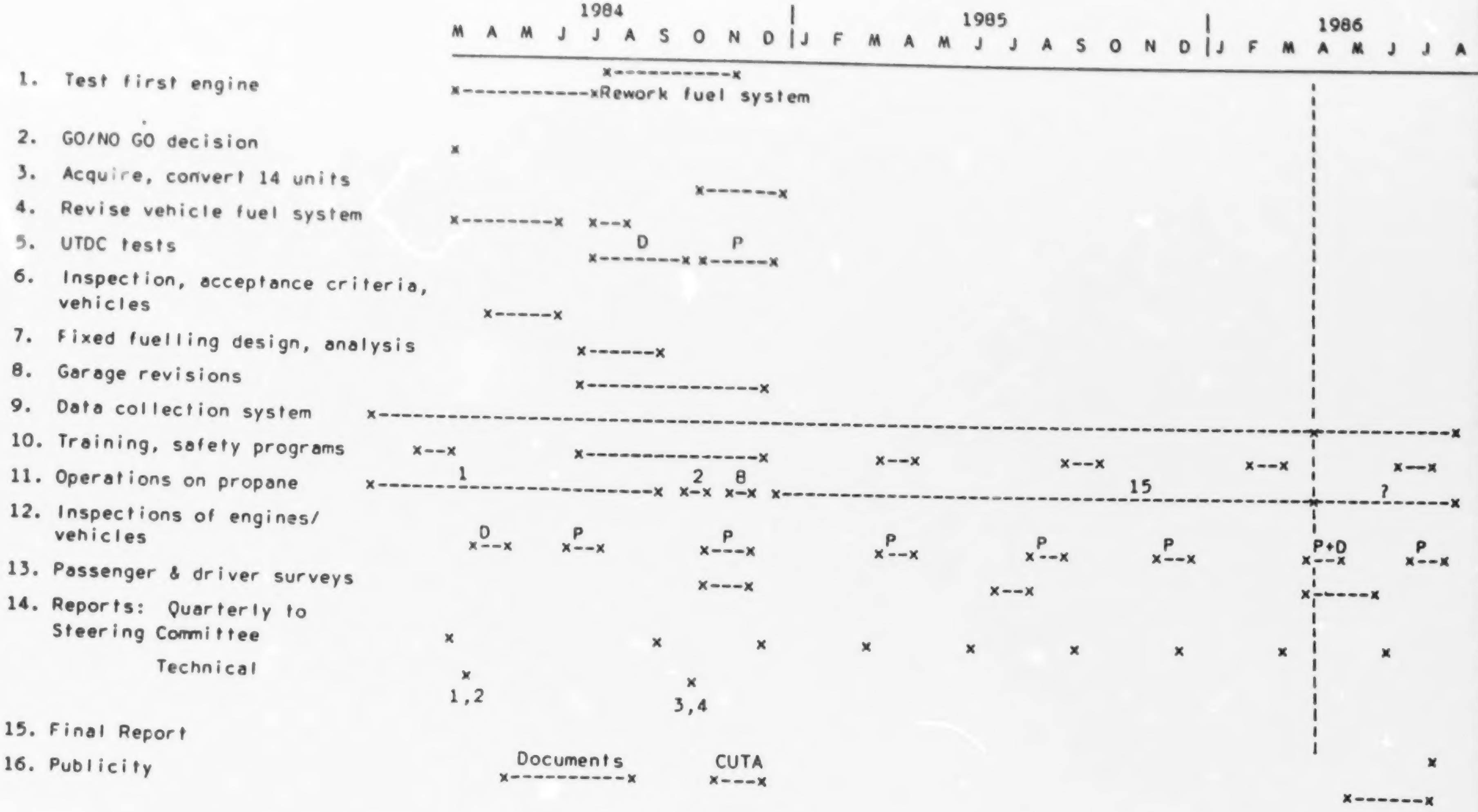
ORGANIZATION FOR PROPANE DEMONSTRATION


MINISTRY OF TRANSPORTATION & COMMUNICATIONS
MTC: Project Monitor
OTTAWA-CARLETON REGIONAL TRANSIT COMMISSION
STEERING COMMITTEE CHAIRMAN: J.A. Bonsall
PROJECT STEERING COMMITTEE MEMBERS:
OC TRANSPO: P.J. Newgard
MTC
MIN. OF ENERGY
EMR
CONSULTANT
PROJECT MANAGER: W.D. Jenkins
EXISTING OC TRANSPO OPERATIONS
ENGINEERING
MAINTENANCE
VEHICLE OPERATIONS
FUELLING
SUPPORT SERVICES
Suppliers
Consultants/Designers
Safety, Fire and other City/Province Agencies

COMPONENTS OF THE PROPANE BUS SYSTEM


FUEL SUPPLIERS
MANAGEMENT
ENGINEERING
SECURITY
COMPONENT AND BUS MANUFACTURERS
BUS CONVERSION
ENGINE TANKS CONTROLS
ROAD TANKER DELIVERY
TRAINING
BUS MANUFACTURERS
PROPANE STORAGE
BUSES IN SERVICE
SAFETY AND ACCEPTANCE TESTS
BUS FUELLING
GARAGING
REPAIR AND MAINTENANCE
VEHICLE SAFETY REGULATIONS
REGULATIONS ON FUEL HANDLING, SITE, EQUIPMENT
FIRE CONTROL

DEMONSTRATION SCHEDULE



MR. J.A. BONSALL
(GENERAL MANAGER, OC TRANSPO)

PRESENTATION - MEETING OF THE CANADIAN URBAN TRANSIT ASSOCIATION

OTTAWA, ONT.
21 NOVEMBER 1984

NOTES FOR JOHN BONSALL

INTRODUCTION TO THE "OC TRANSPO PROPANE BUS DEMONSTRATION PROGRAM"

1. Background

In the 1970's, and still today, OC Transpo continues to search for ways to hold down the increases in operating costs. Outcomes of this search include the development of the bus-based transitways that are now operating, the testing of articulated buses, and the subject of today's presentation, an engineering demonstration of propane-fuelled buses. The decision to investigate propane buses arose from our positive experience in the substitution of propane for gasoline in our service fleet, and indications that more knowledge of propane substitution for diesel in the bus fleet might ready the Commission for decisions that may be needed in the future if problems arise with the supply, quality and cost of diesel fuel, or with new diesel vehicle emission standards.

2. Bus Fuel Trends

The price of diesel fuel to OC Transpo has increased almost ten-fold in the past ten years and the Commission's annual bill for diesel is $10 million - accounting for 14% of our maintenance and operating budget. In 1982, when we began the propane investigation, prices were rising rapidly and had exceeded the 40¢/litre range. Although prices have eased somewhat since then (our current price is about 38.5¢/litre), we expect them to rise again as Canada's oil price is adjusted to the world level and as diesel fuel demand picks up again in step with our emergence from the recession. A recent forecast made for us is that the price of diesel fuel will reach the 49-50¢/litre level (in today's dollars) in less than 10 years - well within the 14-16 year life expectancy of even the new diesel buses we are adding this year to the fleet.

On the other hand, propane is a commodity in large surplus supply in Canada, and future price increases for propane are likely to be tied more to the price of natural gas than to oil and will increase slowly relative to oil. Furthermore, propane in Ontario enjoys the benefit of no provincial sales tax at the moment. This explains the low prices for propane, in the region of 20¢/litre, that are available to large-volume users such as OC Transpo, when a substantial proportion of the fleet consumes propane.

In the late 1970's there was a shortage in the west of Canada of the quality of diesel fuel we must use in the present stock of diesel buses and we are advised that shortages may occur throughout Canada in the future. More of our fuel will be derived from the tar sands and heavy oils of western Canada which give low quality diesel fuel. Demand for the diesel fraction of the refined oil barrel is expected to increase much more rapidly than the demand for other fractions such as gasoline and industrial heating oils. Both these factors will affect diesel fuel supply and quality.

There is increasing interest in improving the quality of the environment. At OC Transpo now we have a downtown mall and other routes which may be especially sensitive to the noise and particulate emissions of diesel engines, and our interest in the propane engine is increased by the fact that it burns quietly with little or no smoke and produces lower levels of odour and carbon monoxide than the conventional diesel engine achieves.

Engines operated on other alternative fuels, such as methanol, liquid or compressed natural gas, are known to have similar low emission levels and may be the engines of choice for other locations, but in this region propane appeared to be the most economic of the alternatives. Initial operation of the first of our test buses has confirmed our expectations on cost and performance, but much remains to be learned about the long-term and winter performance of propane buses in revenue service, of the fuel economy and cost savings that will be available, and about driver and passenger response to the new buses. We hope to exchange data with other properties on their experiences with other alternative fuels during the two-year period of our demonstration.

3. The Propane Demonstration

The propane demonstration at OC Transpo involved the conversion of 15 standard 40-foot GM buses to propane by replacement of the 2-stroke diesel engine with a 4-stroke propane engine specially redesigned for rapid replacement and interfacing to the Allison transmission. The specifications were set so that reconversion of the bus to diesel use could be made if needed at the completion of the demonstration. New fuel tanks were installed in each bus to contain the propane, and other modest changes are being made to provide each propane bus with power output, acceleration and range indistinguishable from that of the standard diesel bus. We elected to make the conversions ourselves and to train and certify the maintenance staff for these new operations.

In additon to changes in the bus, changes are being made at the St. Laurent site to provide a fast-fuelling facility and on-site storage for propane, and within the garage to ensure the segregation and safe handling of the propane bus fleet during its garaging, maintenance and repair.

The test program is a substantial effort and we are grateful to the Ministries of Energy of the province of Ontario and at the federal level for their financial contributions to the program and for the technical help that they and the staff of the Ontario Ministry of Transportation and Communications are providing.

We are happy to have the opportunity this morning of bringing you up-to-date on the demonstration. Our plan is to have our technical consultant for the project, Dr. Reg Webb, review the rationale for the program and the choice of propane, then Peter Newgard, Director of the Equipment Department, will outline the steps that have been taken to select the engine and organize the conversions, training, bus operations and data collection. Bill Jenkins, the Manager of the project at OC Transpo will then describe and interpret the testing that has been conducted to date.

As the final item this morning, we invite you to question a panel we have assembled, which includes representatives of the Ontario government responsible for propane demonstrations, of the propane engine manufacturer Dereco, and our project team.

APPENDIX F

PRESS KIT

OC Transpo

for release: November 21, 1984.

OC TRANSPO INTRODUCES PROPANE

The Ottawa-Carleton Regional Transit Commission (OC Transpo) is introducing its first propane-powered bus into regular service as part of a three-year "Propane in Transit" demonstration project. By late fall of this year, OC Transpo will have completed the conversion of fifteen of its buses to propane.

The goal of the Ottawa project is to determine whether propane is a reliable and economic performer when used to fuel urban transit buses. Propane has proven to be an efficient, clean, quiet, and safe fuel in a growing number of transport applications in Ontario and the rest of Canada. In fact, propane is considered to be the prime alternative fuel for this decade.

Funded by Energy, Mines and Resources Canada, the Ontario Ministry of Energy, and OC Transpo, with technical expertise from the Ontario Ministry of Transportation and Communications, the "Propane in Transit" project will monitor all aspects of vehicle performance, maintenance requirements and public acceptance. The project is one of a number of alternative transport fuel demonstrations being carried out under the Canada/Ontario Conservation and Renewable Energy (EnerDemo) Program, which aims to develop the expertise and experience necessary to gradually reduce the oil-dependency of our transport systems.

OC Transpo General Manager, John Bonsall, who also chairs the inter-agency steering committee directing the project said today, "OC Transpo welcomes this opportunity to help develop the expertise and operating experience with a fuel which may turn out to be an important element in our continuing effort to improve the service we provide to the residents of Ottawa-Carleton. Propane has the promise of improving the quality of the ride and the environment. The promise needs to be investigated. By supporting this and other demonstrations of alternative transport fuels, the government agencies involved are clearly keeping the long-term interests of the public in mind."

For more information, see attached brochure and Background Information or call:
Propane Bus Project Management Office, OC Transpo, (613) 741-6440

OC Transpo

"PROPANE IN TRANSIT"

Background Information

The "Propane in Transit" project is the first urban transit demonstration of propane in Canada. It is being undertaken by the Ottawa-Carleton Regional Transit Commission (OC Transpo) with technical assistance from the Ontario Ministry of Transportation and Communications and funding from Energy, Mines and Resources Canada and the Ontario Ministry of Energy. This project is one of a number of alternative transport fuel demonstrations being carried out under the Canada/Ontario Conservation and Renewable Energy (EnerDemo) Program, which aims to develop the expertise and experience necessary to gradually reduce the oil-dependency of our transport systems.

While the OC Transpo project is a first for Canada, a few transit operations in other countries have been successfully running their buses on propane for a number of years. The most notable is in Vienna, Austria, where a fleet of 400 buses is currently in operation. This operating experience, together with similar results in a wide range of other vehicles here in Canada, suggests that the present demonstration project is both timely and promising.

Rationale and Objectives

Because Canada's present transportation system is almost entirely oil-based, it is vulnerable to the price volatility, supply uncertainty and demand fluctuations associated with petroleum-based fuels. A way of ensuring reliability in this vital sector is to begin using non-petroleum-based fuels such as propane wherever practical. The abundant supply of propane in Canada makes it an attractive fuel option. Large road vehicles, such as buses and trucks, are a strategic application for the use of propane.

The prime objective of the "Propane in Transit" project is to determine the viability of propane as an alternative fuel for city buses. The demonstration will assess the operating and economic feasibility of integrating propane into all aspects of the OC Transpo system including maintenance, garaging, fueling and revenue service. In addition, the impact of the propane buses on the environment will be assessed and public response to the particular characteristics of the propane bus, such as reduced noise, vibration, and exhaust emissions will be monitored.

OTTAWA-CARLETON REGIONAL TRANSIT COMMISSION DE TRANSPORT RÉGIONALE D'OTTAWA-CARLETON
1500 BOUL. SAINT LAURENT BLVD. OTTAWA, ONT. K1G 0Z8 TELEX 053-3828

If successful, the OC Transpo project may help stimulate further applications of propane by transit operators and other large diesel fleets throughout Canada.

Propane as a Transport Fuel

In Canada, propane is primarily a by-product of natural gas processing. Since Canada is blessed with an abundant supply of natural gas, the availability of propane is assured well into the future. At the present time, only half of Canada's propane production is being used domestically; the rest is exported principally to the United States.

Propane has historically been a financially attractive fuel; its price in Ontario is currently about 50% of the price of gasoline and diesel fuel. This price advantage has been enhanced by federal grants and provincial tax exemptions on propane fuel and equipment.

As a transport fuel, propane has a number of advantages.

- While it is stored as a liquid, propane enters engine cylinders completely vapourized, permitting better throttle response and easier cold-weather operation.
- It burns cleanly, resulting in minimal spark-plug fouling and long lubrication oil life. As a result, long engine life is expected.
- Stored under pressure in heavy-gauge steel tanks, propane fuel systems have been demonstrated to be as safe as any other fuel system in crash tests and to meet all other safety standards.
- Because it burns so efficiently, propane combustion produces very low levels of exhaust emissions, especially particulates and carbon monoxide. Similar levels of oxides of nitrogen are measured, compared to the conventional diesel engine.
- A propane-powered engine runs more quietly and with less vibration than most engines.

Converting Buses to Propane

The majority of the existing fleet of OC Transpo buses will serve well into the 1990's before requiring replacement. Consequently, it was decided to convert fifteen of these buses, rather than the more expensive step of ordering entirely new buses for the demonstration.

Since the standard North American diesel engines used in OC Transpo buses are unsuitable for conversion to propane, they are being replaced by new Iveco propane engines manufactured in Europe. This type of engine allows not only the use of propane but also the use of other non-petroleum fuels such as methanol, ethanol, natural gas, or even biogas. If desirable, these highly versatile engines can be converted for diesel use.

The buses must also be fitted with new on-board fuel storage and distribution systems. The propane is stored under pressure in a heavy steel tank equipped with all appropriate safety valves to deliver safely the required fuel flow to the engine.

If propane proves a viable alternative to diesel, new buses might be ordered with propane systems already installed, in addition to the conversion of the existing fleet.

A Tough Test

Commercial transit operations provide a rigorous context for testing any new fuel system. The goal of this demonstration project is to determine whether the fuel/engine combination can work efficiently and economically in the long term. The sponsors will be monitoring vehicle performance, emissions and noise, as well as future price and availability of the fuel in order to determine whether or not the investment needed to bring propane into a typical Canadian transit system is warranted.

For more information, call or write to the Propane Bus Project Management Office, OC Transpo, 1500 St. Laurent Blvd., Ottawa, Canada K1G 0Z8. (613) 741-6440.

a demonstration project

Canada Ontario OC Transpo

A demonstration project is now underway in Ottawa to test propane as an alternative fuel in urban transit. Fifteen OC Transpo buses are being converted to run on propane. These will be put into regular service for a three year period starting in 1984, to test all aspects of vehicle performance, maintenance requirements and public acceptance. In order to keep conversion costs to a minimum, only buses already slated for major engine rebuilding will be converted from diesel to propane.

This project will be the first urban transit demonstration of propane in Canada. It is being undertaken by the Ottawa-Carleton Regional Transit Commission (OC Transpo) with technical assistance from the Ontario Ministry of Transportation and Communications and funding from Energy, Mines and Resources Canada and the Ontario Ministry of Energy. The "Propane in Transit" project is one of a number of alternative transport fuel demonstrations being carried out under the Canada/Ontario Conservation and Renewable Energy (EnerDemo) Program which aims to develop the expertise and experience necessary to gradually reduce the oil-dependency of our transport systems.

The resulting assessment of the costs and benefits of using propane in transit will provide OC Transpo and other transit operators across Canada with a basis for subsequent decisions on the use of propane.

Canada's present transport system is almost entirely oil-based, leaving it vulnerable to the price volatility, supply uncertainty and demand fluctuations associated with petroleum-based fuels. Since large diesel engines move most of the people and freight on road, rail and water in Canada, and since transit buses in particular use a significant portion of our diesel fuel supply, urban transit is a strategic environment in which to test an alternative fuel system. Using non-petroleum-based fuels such as propane wherever practical is a way of ensuring flexibility and cost containment in this vital sector.

Propane is being used increasingly in vehicles ranging from farm tractors and school buses to taxi cabs and delivery trucks. Several factors have contributed to the choice of propane as the alternative fuel for this demonstration project.

- Canada currently produces twice the propane it uses; most is produced from natural gas of which there is a secure, long-term supply available at low cost relative to crude oil.
- Both federal and provincial governments encourage the use of propane through a variety of measures such as grants and tax exemptions on both fuel and conversion equipment.
- Propane is non-toxic and has proven to be as safe as conventional fuels.
- Propane burns more efficiently than gasoline or diesel, producing lower overall exhaust emissions.
- Propane-fueled engines run more quietly than diesel-fueled engines.

Because a commercial transit operation is one of the most demanding environments in which to test a new fuel system, sponsors believe this project will demonstrate whether the reliability and economy of propane can match its environmental advantages and hence warrant its introduction as a complement to diesel fuel in urban transit. OC Transpo's findings are certain to be of interest to transit authorities throughout Canada.

For more information, write for the *"Propane in Transit"* kit, Propane Bus Project Management Office, OC Transpo, 1500 St. Laurent Blvd., Ottawa, Canada K1G 0Z8.

APPENDIX G

CONTRACT

MEMORANDUM OF AGREEMENT made in triplicate this 15th day of November, A.D. 1983,

BETWEEN:

HER MAJESTY THE QUEEN in right of the Province of Ontario as represented by the Minister of Transportation and Communications, hereinafter referred to as the "Minister"

OF THE FIRST PART

-and-

OTTAWA-CARLETON REGIONAL TRANSIT COMMISSION

hereinafter referred to as the "Commission"

OF THE SECOND PART;

WHEREAS the Minister desires to investigate the feasibility and cost-effectiveness of operating propane-powered buses in revenue service in urban municipalities;

AND WHEREAS the Commission desires to conduct a demonstration project to carry out the aforesaid project.

NOW THEREFORE WITNESSESTH that in consideration of the terms and conditions hereinafter provided and the mutual convenants of the parties herein contained, it is agreed as follows:

1.0 Description of Work

1.1 The Commission, in co-operation with the Minister, shall carry out a demonstration of the technology and economics of propane-powered buses and assess the fuelling and maintenance costs as well as general public, customer and driver acceptance relative to the diesel-powered bus in actual revenue service as described in Schedule A.

1.2 This work is part of a program being carried out jointly by the Minister, the Ontario Ministry of Energy, and Energy, Mines and Resources Canada under a Canada/Ontario agreement dated the 16th day of May, 1979.

1.3 The Minister will provide the assistance as set out in Schedule G.

2.0 Commission's Warranties

2.1 The Commission is a corporation wholly owned, directly and indirectly, by persons resident in Canada and is duly registered and qualified to do business wherever necessary to carry out its present business and operations and the terms of this Agreement.

2.2 All work and services to which this Contract applies shall be performed in a good and workmanlike manner and to a high standard of professional competence and shall be suitable for the purpose specified in paragraph 1.1 and the Schedules.

2.3 Acceptance or approval of any work or services by the Ministry of Transportation and Communications (hereinafter referred to as the 'Ministry') officials, whether express or implied, shall not alter the Commission's responsibilities under this Contract.

3.0 The Commission agrees to:

3.1 Purchase propane engines from Diesel Engine Research and Engineering Company Limited, (formerly Adolph Saurer Limited and hereinafter referred to as "DERECO"), Schlossgasse, 9320 Arbon, Switzerland, in response to the generalised specification reproduced in Schedule I; implement the modification of the required number of the Commission's General Motors buses as outlined in Schedule B; and subject to the review of the

...3/

Steering Committee, install fixed fuelling facilities following the procedure outlined in Schedule D.

3.2 Purchase a spare parts inventory for those items of equipment not normally available from established suppliers in Ontario.

3.3 Provide appropriate special tools and portable shop equipment for the regular servicing and maintenance of the vehicles, as set out in Schedule G.

3.4 Execute an inspection program, as outlined in Schedule F to determine the acceptability of the propane-powered buses.

3.5 Obtain any necessary municipal authority to operate the propane-powered buses.

3.6 Operate and maintain the propane-powered buses to normal standards of the Commission provided the cost incurred thereby during the demonstration project shall be eligible for normal operating subsidies.

3.7 Determine the application and allocation of the propane-powered buses, and operate said vehicles such that the objectives of the demonstration project are achieved.

3.8 Co-operate with the Minister in defence of any claims which may be made against either of the parties arising out of the operating of the vehicles covered by this agreement.

3.9 Identify the information that will be required for analysis in order to realize the purpose of the demonstration project.

3.10 Maintain detailed records of operating and maintenance information associated with the demonstration project and obtain such additional data as the Minister may from time to time request to assess the operating characteristics (maintenance, vehicle performance, etc.) of the demonstration project (before and during the demonstration project). The aforesaid information shall, upon request, be provided to the Minister.

3.11 Not assign, transfer or otherwise dispose of any right or title or interest resulting from this agreement without prior written approval of the Minister.

3.12 The release or exchange of information, data or findings resulting from this demonstration project shall have prior written approval of the Minister.

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4.0 Cost

4.1 The Minister shall pay the Commission the fees set out in Schedule G. The total amount payable to the Commission by the Minister shall not exceed $975 000.00.

5.0 Billing

5.1 The Commission shall invoice the Minister monthly for any portion of the contract performed during that month, and the Minister shall make interim payments to the Commission after receipt and approval of such invoices, up to the maximum stated in paragraph 4.1.

5.2 Every invoice shall be accompanied by a statement indicating:

5.2.1 the name of the Commission;

5.2.2 date and file reference of this contract;

5.2.3 the total amount for which the invoice is rendered and a cost breakdown by item (using categories listed in Schedule G);

5.2.4 the estimated remaining expenditure for each item;

5.2.5 the total amount invoiced under this contract to date;

5.2.6 a brief description of the work performed;

5.2.7 an estimate of the work which has been performed to date as a percentage of the total work for each item; and

5.2.8 details of any disbursements.

5.3 Failure to provide the appropriate information as part of the invoice may result in delays or total rejection of the invoice.

6.0 Time

6.1 The work shall commence no later than the 1st day of September, 1983, and be completed not later than the 31st day of August 1986.

6.2 Where the Commission requires an extension of time to complete the work, the Commission shall, within a reasonable time prior to the date for completion, give the Minister notice in writing. The time for completion shall not be varied except by the Minister in writing.

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Such permission shall not be unreasonably withheld and due allowance will be given for all delays not caused by actions of the Commission.

7.0 Reports

7.1 The Commission shall submit reports to the Minister as set out in Schedule E.

7.2 A final report will be submitted upon completion of the work. The final report shall contain data required under the Canada/Ontario Conservation and Renewable Energy Demonstration agreement.

8.0 Personnel

8.1 All work shall be performed by the persons deemed most suitable by the Commission to ensure that the demonstration project is conducted in an efficient manner, such that the objectives of the demonstration project are achieved.

9.0 Steering Committee

9.1 A Steering Committee shall be established to advise the Commission's project team, to monitor progress and to report to the Minister. The committee shall comprise representatives from the Ministry, Energy, Mines and Resources Canada, the Ontario Ministry of Energy, and representatives of the senior management of the Commission, including the General Manager (who would be the chairman of the steering committee). Decisions shall be made by consensus among the above-mentioned members of the committee. An independent technical consultant will provide progress reports, analyses and independent recommendations to the committee.

10.0 Indemnification and Insurance

10.1 The Minister, the Ontario Ministry of Energy and/or Energy, Mines and Resources Canada shall not be liable for any bodily injury, death or property damage to the Commission, its officers, employees or agents which is in any way related to the Commission's work under this Contract, unless the injury, death or damage is caused by the negligence of a Ministry employee while acting within the scope of his/her employment.

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10.2 The Commission shall at all times indemnify the Minister, the Ontario Ministry of Energy, and Energy, Mines and Resources Canada, their employees and agents from all claims or losses by any persons which are related to any action of omission of the Commission, its officers, employees, or agents in connection with work performed, purportedly performed or required to be performed, by the Commission under this Contract.

10.3 The Commission shall maintain in full force and effect insurance in respect of third party, public liability and property damage subject to the Commission being entitled to insure itself to the sum of Five Million Dollars ($5 000 000) for each separate occurrence resulting from the operation of such vehicles and the Commission agrees to indemnify and save harmless the Minister, the Ontario Ministry of Energy, and Energy, Mines and Resources Canada from any and all claims for injuries or damages due to the operation of any such vehicles in excess of the limits of such insurance.

10.4 In no event shall the Minister, the Ontario Ministry of Energy, and Energy, Mines and Resources Canada or any of them be liable for any incidental, indirect, special or consequential damages or any loss of use, revenue or profit of the Commission, its employees, agents or sub-contractors arising out of or in any way related to this Agreement or the work.

10.5 The Commission warrants that the work will not infringe upon or violate any patent, copyright, trade secret or any other proprietory right of any third party.

11.0 Cancellation

11.1 The Minister may cancel this Contract at any time upon one month's written notice to the Commission. The Commission may cancel this Contract at any time upon one month's written notice to the Minister provided that the accumulated sum charged to the Minister, including cancellation costs, will not exceed the project limit specified in paragraph 4.1.

11.2 If this Contract is cancelled pursuant to paragraph 11.1, this Contract shall be of no further force except that:

11.2.1 The Commission shall continue to be responsible for its warranty under paragraph 2.2 in relation to all work and services performed by it before such cancellation;

11.2.2 The Commission shall be entitled to a full reimbursement for all work, outstanding orders and services performed by it before such cancellation, except such work and services which, in the opinion of the Minister, do not conform to paragraph 2.2;

11.2.3 The Commission shall be entitled to a full reimbursement for all work and materials required to return the Commission's propane-powered bus fleet and associated facilities to diesel-powered operation. The maximum amount payable by the Minister for this work shall be $160 000.00 which includes $6 000.00 for each of the 6-V-71 diesel engines removed, up to a maximum of sixteen (16) engines; and

11.2.4 Articles 12 and 13 shall continue to apply.

12.0 Intellectual Property

12.1 The copyright in all material arising out of the work shall belong to Her Majesty the Queen in right of Canada and in right of Ontario, as tenants in common.

12.2 The Commission shall own all other intellectual property arising from the work, including patents, industrial design, and other intellectual or industrial property and all applications therefor.

12.3 Upon completion of the work, or earlier if requested, the Commission shall report to the Minister on the accumulated knowledge, experience, know-how, secret processes, formulae, technology, techniques, procedures, studies, inventions, test results, programs including computer programs and software, and technical and other information arising from the work and shall provide copies of all relevant documents, including data and plans.

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12.4 The Commission grants to Her Majesty the Queen in right of Canada in right of Ontario, a non-exclusive royalty-free licence to use everything mentioned in paragraphs 12.2 and 12.3.

12.5 Her Majesty the Queen will grant to the Commission a non-exclusive royalty-free licence to copy or publish material in which She has copyright under 12.1, provided that Her financial support is prominently acknowledged in every such publication.

12.6 At any time more than 2 years after completion of the work, the Commission will, at the request of the Minister, assign to Her Majesty the Queen in right of Canada and right of Ontario as tenants in common all intellectual property owned by the Commission arising out of the work, unless the Commission satisfies the Minister that the Commission has made all reasonable efforts to develop and market in Canada the things to which the property relates, at a reasonable price.

13.0 Confidentiality

13.1 The confidentiality of the work shall be at the discretion of the Minister both during the term of this Contract and thereafter. Subject to 13.2, no information about the work shall be divulged without the prior written consent of the Minister.

13.2 Any information respecting the Contract may be given, on request, to members of the Management Committee appointed under the Canada/Ontario agreement mentioned in paragraph 1.2, (or their representatives).

14.0 Conflict of Interest

14.1 The Commission shall ensure that it can undertake and complete the work without a conflict of interest. During the course of the work the Commission shall not undertaken any work for another client that could reasonably result in a conflict of interest, without the prior written consent of the Minister.

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15.0 Notices

15.1 Any notice required to be given under this Contract shall be given to the party to whom it is addressed,

15.1.1 by personal delivery to that party, in which case the notice shall be deemed to have been given on the day of the delivery; or

15.1.2 by prepaid post to the postal address of that party, in which case the notice shall be deemed to have been given with the expiration of the fifth day after the date of mailing.

16.0 Designated Ministry Representative

16.1 The Designated Ministry Representative shall be the person identified in a letter from the Minister to the Commission. The Minister may designate different personnel by notice in writing to the Commission.

17.0 Additional Terms

17.1 The terms of this Agreement shall run for a period of thirty-four months from the date of receipt of the first aforesaid propane-powered engine by the Commission from the engine manufacturer.

17.2 As required by the Schedules, signs and publicity in accordance with Ministry specifications will be constructed and displayed by the Commission.

18.0 Publicity

18.1 Any report, announcement, brochure, audio visual material or other public communication or publication relating to this Agreement or the work, as well as any official opening ceremony related thereto, shall be first approved by the Minister and will reflect the participation of each party in the work.

18.2 The Commission shall supply, install and maintain decals on the buses and associated equipment involved in the demonstration during its course and for a period of one year after its completion. All signs shall be consistent with provincial

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identifying graphic guidelines specifying that the relevant work is financed by contributions from the Ministry and Energy, Mines and Resources Canada.

19.0 Inspection

19.1 The Minister and his representatives shall be entitled to review, during normal business hours, all results of the work and all records, documents, reports, accounts, or other materials of the Commission relating to the work.

20.0 Compliance with Applicable Laws

20.1 The Commission represents and warrants that the work will be carried out in compliance with the laws of Canada and the provinces, as applicable.

21.0 No Waiver

21.1 The failure of any part to enforce at any time or for any period of time the provisions hereof shall not be construed to be a waiver of such provisions or the right of such party thereafter to enforce each and every such provision. Waiver of any breach shall not be deemed a waiver of any other breach, even if similar in nature.

22.0 Canadian Preference

22.1 When purchasing supplies for the purpose of this Agreement, the Commission agrees to give preference to Canadian suppliers where all other factors are equal.

23.0 Changes

23.1 The Minister or Commission shall immediately upon becoming aware thereof give the other party notice of any Changes which it considers necessary or desirable.

23.2 Promptly upon receipt of or in giving notice pursuant to Section 23.1, the Commission shall give the Minister notice of:

(a) any supplements, amendments, modifications or changes in the Contract necessary to provide for such Changes;

(b) any extension of the target dates set out in Schedule H that will be necessary if such Changes are performed or furnished; and

(c) the estimated cost revision resulting from such Changes.

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23.3 The decision to proceed with any Change as outlined in 23.1 and 23.2, shall be arrived at through mutual agreement between the Commission and the Minister.

24.0 Entire Contract

24.1 This Contract including the Schedules,

Schedule A Terms of Reference
Schedule B Commission's Tasks
Schedule C GO/NO GO Test Procedure
Schedule D Installation of Fixed Fuelling Facilities
Schedule E Reports
Schdeule F Inspection
Schedule G Fees and Other
Schedule H Programme Schedule and Cash Flow
Schedule I Propane Engine and In Vehicle Fuel System Performance Specifications

constitutes the entire Contract between the parties. There are no prior or collateral agreements or representations.

24.2 This Contract shall not be varied except by a document in writing, dated and signed on behalf of the Minister and the Commission, and attached to the original Contract on file at the Ministry. A copy of any letter of variation shall be supplied to the Commission.

24.3 The execution of this Contract shall permit immediate commitments to be made by the Commission to further the execution of the demonstration project. These commitments will be phased such that expenditures are incurred to achieve, to the best of the Commission's ability, the Minister's annual budget estimates for this demonstration project.

DATE ______________________________
For the Minister

DATE Dec 15 1983 ______________________________
For the Commission

DATE Nov 15 1983 ______________________________
For the Commission

SCHEDULE A

Attached to and forming part of Contract between Ottawa-Carleton Regional Transit Commission and Her Majesty the Queen dated this 15th day of November, A.D. 1983.

TERMS OF REFERENCE

Ministry Objective

To carry out a demonstration of the technology and economics of propane utilization as a transportation fuel for transit fleet vehicles, and to assess the reliability, safety, operability, and public response to propane-fuelled buses in urban transit service.

Commission's Responsibility

1. The Commission will be responsible for the development of the detailed plan for the demonstration, for the acquisition of the required components and facilities and for the preparation and presentation of results and reports.
2. The Commission's project team will report program status to the Steering Committee, which in turn, will provide advice to the Commission and will report to the Minister.
3. The Commission's Task's are outlined in Schedule B.
4. The initial project evaluation and test procedures are outlined in Schedule C.
5. The project report format is outlined in Schedule E.
6. The project inspection format is outlined in Schedule F.
7. The project budget is outlined in Schedule G.
8. The project schedule and cash flow are given in Schedule H.
9. The Commission will provide publicity to the demonstration program, including the display of decals on the propane-powered buses and fuelling facilities, identifying both the Ontario Government's and the Federal Government's contributions to the demonstration programme and presentations at the OUTA and CUTA Conference or annual meetings. The results obtained from the demonstration shall be disseminated according to the procedure outlined in the Enerdemo report entitled "Proponents Guidelines for Information Transfer".

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10. All monies received by the Commission, from the sale of the equipment outlined in Schedule G at the conclusion of this demonstration, shall be credited to the Minister.

SCHEDULE B

Attached to and forming part of Contract between Ottawa-Carleton Regional Transit Commission and Her Majesty the Queen dated this 15th day of November, A.D. 1983.

Commission's Tasks

1. Ensure that the propane and diesel engines which DERECO propose, will be accommodated within the existing General Motors bus engine compartment without any major structural or bodywork modifications. DERECO are to supply a "dummy" engine for this purpose. Initiate any body or engine modificatons found necessary as a result of fitting the "dummy" engine. Advise the Minister if required modifications, in the opinion of the Commission, prevent the reasonable and advisable installation of DERECO engines in the General Motors buses.
2. With the successful completion of step 1 above, order one (1) DERECO propane engine and one (1) DERECO diesel engine, plus all necessary ancillary components to install these engines in General Motors buses.
3. Install the DERECO propane engine and DERECO diesel engine into existing Ottawa-Carleton General Motors buses.
4. Evaluate the DERECO propane-powered bus with respect to the DERECO diesel-powered bus and a standard Detroit Diesel Allison diesel-powered bus. Evaluation criteria will be as outlined in Schedule C.
5. Upon evaluation of the test results by the project team, a recommendation shall be made to the Steering Committee that the demonstration project should be completed or terminated.
6. If the Steering Committee approves the recommendation to continue, the project team will proceed as described below.
7. Initiate design, equipment acquisition and installation of fixed fuelling facilities as outlined in Schedule D.
8. Order fourteen (14) more propane-powered engines from DERECO and install them into exising Commission transit buses.
9. A contract shall be signed between the Commission and the Urban Transportation Development Corporation (hereinafter called "UTDC")

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for engine dynamometer testing of the DERECO propane and Detroit Diesel 6-V-71 engines the cost of which shall not exceed the amount specified in item 6 of Schedule G. The contents of the contract shall be supplied by the Minister.

10. Upon receiving the first delivery of seven (7) propane engines from DERECO, one (1) propane engine shall be shipped, complete, to UTDC for dynamometer testing.

11. Detroit Diesel Allison 6-V-71 engines removed from the converted buses shall be retained and stored by the Commission. the value of each complete engine assembly shall be $6 000.00. This value shall be credited to the Commission's surface capital asset account with the Minister, at the time each diesel engine is replaced by a propane engine.

    The spare diesel engines may be used by the Commission as replacements in the regular diesel fleet, at which time normal operating subsidy may be claimed for the rebuilding costs incurred on the diesel engines being replaced by spare engines.

12. Ensure that buildings and maintenance facilities are adequately equipped and/or modified to enable the propane-powered buses to be accommodated at the St. Laurent facility, and that all Safety Standards necessary for maintaining propane-powered buses at this facility are met.

13. The planned program for the purchase, installation and initial testing of fifteen (15) DERECO propane engines, one (1) DERECO diesel engine fuel systems and controls will be carried out over a twelve month period (approximately) from the placement of the order for fourteen (14) propane engines. Engineering assistance from the engine manufacturer in the initial installation is scheduled and similar engineering assistance from suppliers is to be available on a demand basis throughout the demonstration period, but Commission engineering and maintenance staff will perform the conversions and initial tests at the St. Laurent facility. Certain new test equipment particular to propane engines will be purchased and installed as well as tachographs to record cycle characteristics in actual operation.

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14. The total testing, operating and monitoring program will be carried out over a 34 month period. Full records will be maintained on the components used, conversion problems, engine settings, results of dynamometer tests on the engine, safety checks on the in-vehicle fuel storage equipment and controls, together with all other factors necessary to the subsequent monitoring and anaylsis of the demonstration. In addition, records will be maintained which may assist other properites in their conversion to propane.

15. Final reports and documentation will be prepared for the Ministry and under the direction of the Steering Committee.

16. The test vehicles may be remodified to return to the use of Detroit Diesel engines and diesel fuel systems at the conclusion of the progamme.

SCHEDULE C

Attached to and forming part of Contract between Ottawa-Carleton Regional Transit Commission and Her Majesty the Queen dated this 15th day of November, A.D. 1983.

GO/NO GO Test Procedure

Following receipt of the first propane engine and the diesel engine, testing is to be carried out at the Blainville test facilities of Transport Canada and in revenue service in Ottawa-Carleton acording to the following procedure. The result of these tests will be used by the Steering Committee in making its decision to purchase the remaining fourteen (14) engines. A decision to proceed with this purchase will be made if the testing has demonstrated that the propane bus has satisifed the minimum test criteria.

1. Testing will involve three (3) existing Ottawa-Carleton Transit buses, one bus powered by a Detroit Diesel Allison 6-V-71 equipped with C-55 injectors, one bus converted to DERECO diesel power and one bus converted to DERECO propane power, and all tuned to manufacturer's specifications.
2. The buses shall be of the same model. The drivetrains (i.e., transmission construction and final drive gear ratios), tire size, as well as any other vehicle dimensions or equipment configuration which may affect performance between the three (3) vehicles must be exactly the same or have the same effect on each vehicle. Difference in vehicle weights shall reflect the engine/fuel systems installed.
3. The buses shall be operated at Blainville under the Advanced Design Bus (ADB) cycle defined in Attachment 1 to this schedule. A minimum of five (5) ADB cycles shall be run by each bus on the Blainville test track. The fuel consumption figures obtained for each bus from these tests must have a maximum spread of 5% of their mean value.
4. The mean fuel consumption for each bus shall be computed from the five acceptable numbers obtained from the aforementioned track

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testing and shall be expressed in units of "litres per 100 kilometers" (L/100 km).

5. The buses shall be operated during a period of not less than 30 days in regular revenue service in the Commission's operating region. The Commission will determine the Service routes on which the buses will operate to provide operational data to complement the Blainville test data. The fuel consumption shall be determined at the conclusion of this period for the buses and shall also be expressed in terms of L/100 km.
6. The Fuel Utilization Ratio (FUR) is defined as the mean fuel consumption of the DERECO propane-powered bus in L/100 km divided by that of the 6-V-71 diesel-powered bus in L/100 km.
7. The FUR shall be calculated for the Blainville track testing and also for the revenue service at OC Transpo. If the FUR exceeds 1.80 for either phase of testing (Blainville or revenue) the remainder of the demonstration shall be terminated, subject to the detailed review by the Steering Committee.
8. The results of all tests will be submitted to the Steering Committee with a recommendation concerning the purchase of the remaining (14) engines.

ATTACHMENT 1 TO GO/NO GO TEST PROCEDURE

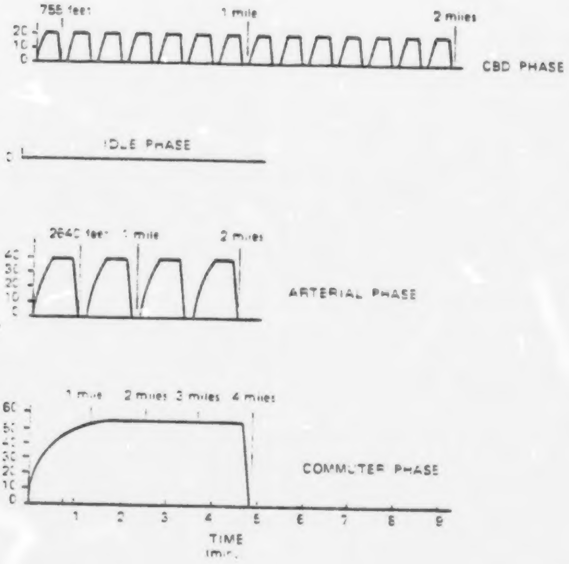
This attachment forms part of Schedule C

The ADB Duty Cycle

KEY CHARACTERISTICS OF THE ADB DUTY CYCLE

Phase	Stops/Mile	Top Speed (mph)	Miles	Approximate Acceleration Distance (ft)	Approximate Acceleration Time (sec)	Approximate Cruise Distance (ft)	Approximate Cruise Time (sec)	Approximate Deceleration Rate (fpsps)	Approximate Deceleration Distance (ft)	Approximate Deceleration Time (sec)	Approximate Dwell Time (sec)	Approximate Cycle Time (min-sec)	Total Stops
CBD	7	20	2	155	10	540	18.5	6.78	60	4.5	7	9-20	14
Idle	-	-	-	-	-		-	-	-	-	-	5-0	-
Arterial	-	40	2	1035	29	1350	22.5	6.78	25.5	9	7	4-30	4
CBD	7	20	2	155	10	510	18.5	6.78	60	4.5	7	9-20	14
Arterial	2	40	2	1035	29	1350	22.5	6.78	25.5	9	7	4-30	4
CBD	7	20	2	155	10	510	18.5	6.78	60	4.5	7	9-20	14
Commuter	1 stop for phase	Maximum or 55	4	5500	90	2 mile + 4580 feet	188	6.78	480	12	20	5-10	1
Total			14									47-10	51

Graphical Presentation of ADB Duty Cycle



Note: This information is taken from Transit Bus Energy Efficiency and Productivity by Booz, Allen & Hamilton, Inc. and published by the Transportation Research Board, Washington, D.C. July 1982.

SCHEDULE D

Attached to and forming part of Contract between Ottawa-Carleton Regional Transit Commission and Her Majesty the Queen dated this 15th day of November, A.D. 1983.

Installation of Fixed Fuelling Facilities

A study will be initiated by the Commission to confirm the advisability, and the economic and operational feasibility of installing fixed fuelling facilities on Commission property as part of this demonstration project. Completion of the study will result in a recommendation by the Commission to the Steering Committee.

If the approved recommendation is negative, then fuelling would be accomplished either off-premises or by having mobile equipment carry out daily fuelling on site.

If the approved recommendation is positive and if the decision has been taken to purchase the 14 propane engines, then a series of tasks aimed at the installation, operation, maintenance and monitoring of the propane storage facilities and fuelling facilities will be carried out in conjunction with the vehicle conversions. The design of the bulk storage system and fuelling islands will be completed in conformity to Ontario and national safety standards and accepted practice. Advice from European properties familiar with propane in transit operations, and from Canadian propane and fuel system suppliers, will be used. Close contact will be maintained with the local authorities to ensure that local safety regulations and requirements are met.

Appropriate site plans, detailed drawings of the required roadway and facilities, operating manuals and other documentation will be prepared, together with a monitoring and reporting system on fuel use, fuel costs and facility safety: this will be issued in a Fuel Facility Report.

SCHEDULE E

Attached to and forming part of Contract between Ottawa-Carleton Regional Transit Commission and Her Majesty the Queen dated this 15th day of November, A.D. 1983.

REPORTS

Reports submitted to the Minister shall follow the format outlined in the "Enerdemo Report Writing Guidelines".

Quarterly Reports

This schedule consolidates the quarterly reporting task on equipment acquisition, the status of conversion, bus and fuel system operation and other items which will be determined by the Steering Committee appointed for the demonstration project. Each quarterly report shall document the following:

A summary of the status of the demonstration,

A description of tasks completed in comparison with milestones set,

A description of major problems to be resolved and solutions, major deviations from the plan, innovations and lessons learned

A cost summary, and

A technical summary report.

The quarterly reports will be prepared by the Technical Consultant of the project team and reviewed with the Steering Committee.

Final Reports

A draft of the final report on the demonstration will be available wihtin 38 months of the initiation of the project. It will be submitted by the project team and reviewed by the Steering Committee, with the final report issued by the Chairman of the Steering Committee, and will contain;

An executive summary,

A technical report on the operation of the system,

A report on the response of the passenger public and the community in the demonstration,

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An interpretative report in which the cost-effectiveness of the propane system, safety and acceptability will be examined and possible improvements suggested,

Recommendations concerning continution or expansion of the propane bus system at OC Transpo. Steps which could be taken by governments, bus properties, fuel and bus suppliers to expedite large-scale use of propane in urban transit operations are to be defined, and

Recommendations for the design and operating procedures for a propane bus operation.

SCHEDULE F

Attached to and forming part of Contract between Ottawa-Carleton Regional Transit Commission and Her Majesty the Queen dated this 15th day of November, A.D. 1983.

Inspection

Each vehicle selected for conversion will be inspected after conversion to verify that it is in safe, efficient operating condition. The Steering Committee shall develop a detailed set of Inspection criteria in the event that phase two of the demonstration project is to be completed. These criteria will be such that a detailed analysis of the project results shall enable positive and quantifiable conclusions to be reached on the feasibility and cost-effectiveness of operating propane-powered buses in revenue service in urban municipalities.

SCHEDULE G

Attached to and forming part of Contract between Ottawa-Carleton Regional Transit Commission and Her Majesty the Queen dated this 15th day of November, A.D. 1983.

FEES AND OTHER

1.	One-time Engine Development cost for unique installation in a General Motors Bus	120 000SFr*	$ 72 720.00
2.	Propane Engine Acquisition	480 000SFr**	276 000.00
3.	Diesel Engine Acquisition (* Converted @ previous exchange rate of 1 SFr = $0.606) (**Converted @ current exchange rate of 1 SFr = $0.575)	32 000SFr**	18 400.00
4.	All Other In-Vehicle Items (tanks, etc.)		82 000.00
5.	GO/NO GO Testing at Blainville		10 000.00
6.	UTDC Testing		98 000.00
7.	Maintenance Shop Conversions, Tachographs, Equipment		10 000.00
8.	Safety Equipment, Explosion Proofing		8 500.00
9.	Test Equipment Specific to Propane and Pollution		6 000.00
10.	Inventory of Dedicated Parts		7 000.00
11.	Miscellaneous Engineering and Office Equipment		3 000.00
12.	Fuelling Facility - Capital, Lease and Maintenance Cost		60 300.00
13.	Travel		11 000.00
14.	Publicity and Information Distribution		10 000.00
15.	Technical Consulting, Reports		70 000.00
16.	Engineering and Technical Services (DERECO)		38 350.00
17.	Architectural and Drafting (part contract)		43 500.00
18.	Computer Program Additions		5 050.00
19.	Public and Driver Surveys		17 000.00
20.	Conversion Cost, Labour (75% of Total) (15 propane + 1 diesel)		47 520.00
21.	Conversion Costs, Expendable Materials		8 000.00
22.	Maintenance Costs, Vehicles' Increased		41 600.00
	TOTAL ESTIMATED EXPENDITURE		943 940.00
	MAXIMUM ALLOWABLE EXPENDITURE		975 000.00

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ESTIMATED COST TO BE ABSORBED BY OC TRANSPO

1.	Project Management & Administration	57 650
2.	Assigned Engineering Staff	141 500
3.	Secretarial Services	27 100
4.	Staff Training, Training Aids	98 000
5.	Vehicle Inspections, Tests	11 200
6.	Conversion Cost, Labour (25% of Total)	15 840
7.	Contingency	14 050
	TOTAL	365 340

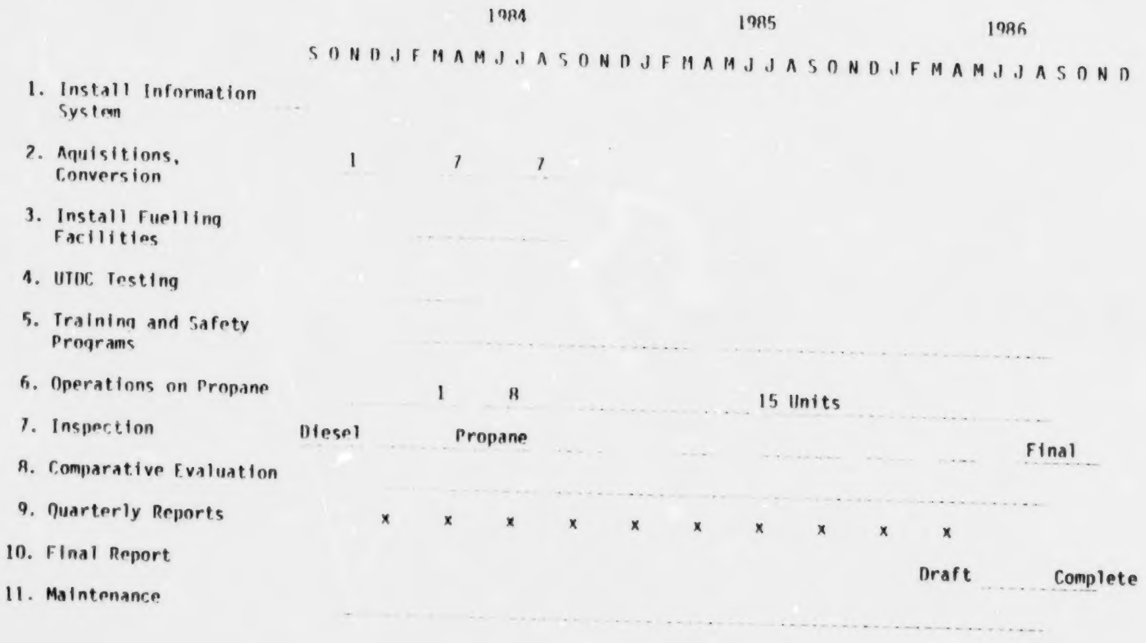
a)	Maximum Expenditure (MTC)	(73%)	975 000.00
b)	Total Expenditure (OC Transpo)	(27%)	365 340.00

GRAND TOTAL 1 340 340.00

SCHEDULE H

Attached to and forming part of Contract between Ottawa-Carleton Regional Transit Commission and Her Majesty the Queen dated this 15th day of November, A.D. 1983.

Programme Schedule



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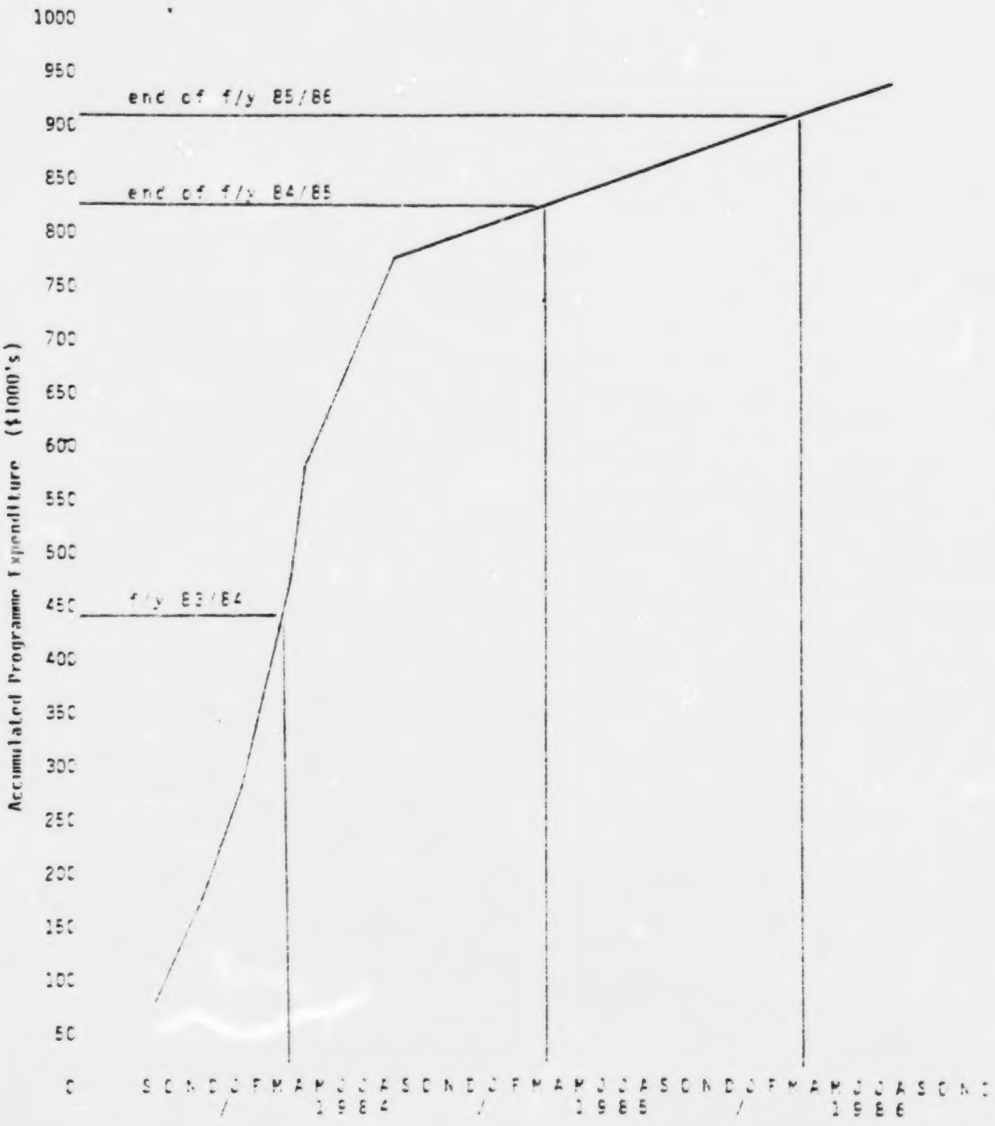
Programme Cash Flow



SCHEDULE I

Attached to and forming part of Contract between Ottawa-Carleton Regional Transit Commission and her Majesty the Queen dated this 15th day of November, A.D. 1983.

1.0 TECHNICAL SPECIFICATIONS FOR ENGINE AND IN-VEHICLE FUEL CONTROLS

1.1.0 Engine Specifications - First Engine

1.1.1 The engine supplied will provide, at minimum, 170 HP peak power; will be equipped with fan and shroud, 12 volt, 300 amp alternator, air compressor, belts and other standard fittings. An exhaust/muffler system, together with a spark ignition system - filter/fuel lock, air intake and filter system, propane vapourizer, carburetor and other items required to meet the specifications given in Attachment 1, and provide effective control and safety. Air compressor output shall be a minimum of 15.5 CFM @ approximately 1250 RPM; cut-out pressure 848-915 kPa; cut-in pressure 703-754 kPa.

1.1.2 The propane engine will be equipped with a special transmission adapter, if that is required in the interfacing of the engine to the GM V730 transmission system.

1.1.3 For the first engine only the vendor will supply the in-vehicle propane storage tank(s), in-vehicle supply lines and valves, brackets and other supports required to secure the storage system in the vehicle and to operate the bus on propane, together with manuals, instruction and assistance in the installation of the fuel storage system in the vehicle provided. The fuel storage system and materials will conform to the prevailing safety standards and regulations applicable in Ontario.

The fuel storage system shall be designed with a working pressure of not less than 2150 kPa (312.5 psig) and provide a minimum propane capacity of 900 litres, or sufficient propane to provide a range of not less than 80 km in the given vehicle

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operated at full speed. The fuel system shall be provided with tank safety devices including: a fixed liquid level gauge; a relief valve; a shut-off valve; an excess flow valve; all in addition to an easily accessible filler valve equipped with an approved automatic shut-off. The in-vehicle fuelling system shall interface with a fast fuel dispensing system and provide no impediment to a 4-minute refuelling cycle.

1.1.4 Optimally, the fuel system may contain a spare (reserve) fuel tank, a gauge to indicate the liquid level in the main propane storage tank, which can be installed to be visible to the seated driver and/or means for the seated driver to activate the reserve fuel tank.

1.1.5 The propane engine shall be designed to comply with applicable 1982 vehicle exhaust emission and noise standards.

1.1.6 The first propane engine installed in the OC Transpo bus shall be operated by the Commission for a period of 30 days, at which time a decision shall be made by the Steering Committee to proceed with Part 2 of the 16 engine purchase and demonstration programme. This programme will be based upon the performance of the propane engine with respect to specifications accepted by the supplier and the delivery by the supplier of manuals, drawings and the satisfactory initiation of the training programme. In the event that the engine specifications are not met, OC Transpo reserves the right to terminate the contract, or to reschedule and revise the remainder of the contract, with the co-operation of the supplier.

1.1.7 In the event that the propane engine does not meet the agreed-upon specifications, the supplier will be required to convert the propane power system to a diesel power system. The conversion back to the diesel system wil be at the supplier's expense.

1.2.0 Engine Specifications - Subsequent Fourteen (14) Engines

1.2.1 The requirement is for the delivery of fourteen (14) propane engines and associated fuel control systems, together with

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such assistance as may be required to complete the training of OC transpo personnel in the installation of:

1.2.1.1 The supplied engines and other components in selected OC Transpo buses identical in configuration with those provided for conversion under Part 1.1.0, and

1.2.1.2 The in-vehicle fuel storage systems purchases by OC Transpo to specifications provided by the supplier under Part 1.1.0 modified where necessary, to reflect installation and safety experience gained in Part 1.1.0 and the 30-day operating test of the first propane vehicle.

ATTACHMENT 1 TO TECHNICAL SPECIFICATIONS

This Attachment forms part of Schedule I

1.0 PROPANE ENGINE AND IN-VEHICLE FUEL SYSTEM PERFORMANCE SPECIFICATIONS

1.1 Weight

The weight of bus, including its full complement of fuel shall not exceed 9800 kg.

(Weight of engine and fuel tank shall not exceed 1225 kg).

1.2 Performance

The propane engine shall be capable of providing 170 HP of power at peak load, capable of giving a satisfactory life and performance under all conditions which prevail in our transit service. The propane-engined vehicle must be capable of maintaining engine RPM of 2100 (full or empty) with smooth acceleration sufficient to achieve a speed of 40 mph (64 kph) in 40 seconds from a standing start on dry level pavement. The propane engine performance shall be such that the acceleration and top speed of the retrofitted bus will equal, or exceed, that of the bus as currently fitted with a GM Detroit Diesel 6-V-71 engine (with C-55 injectors) coupled with the existing V-730 transmission and other existing components. The manufacturer gives the following for the 6-V-71 engine (with C-55 injectors) coupled with the existing V-730 transmission and other existing components. The manufacturer gives the following for the 6-V-71 engine: Fuel - No. 1 Diesel; Injector- C-55; Max. BHP - 170 @ 2100 RPM; Max. Torque - 498 ft-lb @ 1000 RPM.

1.3 Material and Method of Construction

1.3.1 The engine design Materials and placement within the vehicle shall be such that rapid assembly and disassembly shall be possible for maintenance.

1.3.2 The dimensions of all parts, unless specified, will be in accordance with the current standards of the Society of Automotive Engineers.

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1.3.3 All units, or parts not specified shall be supplier's standard units or parts, and shall conform to North American practice.

1.3.4 All parts shall be new and in no case will used or reconditioned parts be accepted.

1.3.5 Unless permission is given in writing by OC Transpo, all parts for all engines shall be exact duplicates in manufacture, design and construction.

1.3.6 Workmanship; supplier's warranties are to be stated.

1.3.7 Engine lubrication must be self-contained and to manufacturer's specification. Type of oil and oil and filter change intervals shall be specified. (OC Transpo has an oil analysis/change programme).

1.3.8 Specification for propane fuel to be used by OC Transpo is provided. The propane engine shall be capable of operating at maximum efficiency with a Canadian grade of propane containing not less than 95% propane and not more than 5% of propylene, or 2.5% of butane by volume. Note that this standard exceeds the Canadian Standard (CAN 2-3.14-M78) which specifies 90% propane and not more than 5% propylene, or 2.5% of butane and heavier hydrocarbons.

1.3.9 Manuals and drawings in English.

1.4 Engine and Accessories

Test Procedures

15 copies of test procedures for the propane carburetion and fuel control system are required with the first delivery.

1.4.1 Engine Design

- HP and torque over the range of engine speeds adequate for bus performance as stated elsewhere in this specification.
- Emissions and noise levels with propane fuel (from supplier's specifications) (smoke, NO_x, hydrocarbon, drive-by test) to meet laws applicable in Ontario.
- Accelerator control by seated driver using existing air-operated throttle.

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- Access to engine and components to permit servicing and replacement in rear of bus with unimpeded access with existing compartment and openings.
- Engine air to be taken from outside bus.
- Engine must be operable from rear of bus, same as existing.

1.4.2 Engine Equipment

It is generally intended that the engine manufacturer be allowed to use his own ancillaries to form a complete power package, bearing in mind the output required for electrical, compressed air, and coach interior heating of the existing vehicle. However, it should be noted by the manufacturer that the overall success of the test could be affected by poor performance of engine subsystems unrelated to propane. Therefore, where possible, it would probably be beneficial to use components similar, or identifcal to those already in use by OC Transpo on its 6-V-71 engines. This could include alternators, air cleaners, air compressors, cartridge-type oil filters, thermostats, flexible hoses, etc.

The following points should be noted:

- Engine temperature thermostatically controlled, as outlined in part 1.4.4 below.
- Power plant designed to permit operation within a sealed compartment with existing insulation and heat shielding.
- Solenoid operated Engine Emergency Stop required similar to existing in the air intake.
- Tachometer adapter required.
- A visual air intake restriction indicator is required similar to current Donaldson Company equipment.
- Oil dipstick should be accessible through existing flap on rear engine door.
- All flexible fuel, oil and air line shall be Teflon type with braided stainless steel cover. All lines must be well supported and resistant to oil, heat and abrasion.

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- Buses are currently equipped with vertical roof level outlet exhaust with dilution aspirator. A bottom exhaust would be acceptable.
- The exhaust system supplied should ensure that maximum noise level under full throttle acceleration does not exceed 84 DBA at the ear level of a seated passenger at all interior locations and does not exceed 78 DBA measured at a point 50 feet from the engine centreline and perpendicular to the direction of travel. It is expected that noise levels will, in fact, be sigificantly lower than these values.

1.4.3 Propane Carburetion and Ignition System

- A low maintenance, transistor coil ignition system comprising a distributior, coil and a switch is to be employed. The ignition timing is to be adjusted for optimum propane consumption as a function of engine speed.
- A vacuum governor is to be provided for the throttle.
- The in-vehicle fuel system is to consist of a filter fuel lock, vapourizer and carburetor, together with fuel controls of a design which has already received N. American safety certification, such as that provided by the U.S. Underwriter's Laboratory. More specific details of the fuel system are given below:

Filter

At the termination of every propane service pipeline, immediately before entry to the automatic shut-off valve, there shall be fitted a properly designed filter capable of removing from the fuel all matter that could cause malfunction of the shut-off valve, or pressure regulator.

Automatic Shut-off Valve

An automatic shut-off valve shall be installed immediately after the filter and before the pressure regulator. This valve shall be in the closed position whenever the ignition control is in the off, or accessory position, and also when the engine is not running.

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Pressure Regulators and Heat Exchanger

The regulator heat exchanger assembly shall be capable of withstanding a minimum inlet pressure of 10 MPa and shall be designed to give the working pressure required.

The regulator assembly shall be securely mounted in the engine compartment protected from exhaust heat and, as far as practical, from the vehicle extremities. It shall not be attached to the engine assembly.

The heat exchanger shall be connected to the heat source designated by the equipment manufacturer (cooling system).

The cooling system/heat exchanger may contain a specified antifreeze and otherwise be assembled to provde fuel vapourization through an operating ambient temperature range of +30°C to -35°C.

The fuel system shall include a block heater and controls, or other means necessary to provide engine start-up after overnight (12 hour) vehicle soak at -35°C.

The design of the propane control system and its location in the engine compartment shall be such that the equipment will be:

- Installed in positions that are accessible for routine inspection, maintenance and adjustment.
- Securely mounted and reasonably protected from damage in a collision.
- Remote from the vehicle engine exhaust system or protected therefrom by a metal shield.
- No closer than is avoidable to any electrical equipment capable of sparking.
- The supplier shall provide a procedure for the testing of the fuel delivery and control system for correct functioning and for the safe disassembly of the propane fuel and control system for the purpose of inspection, repair, or maintenance.

1.4.4 Cooling System

In general, the engine shall be designed to integrate with the existing bus cooling system. The temperature of the existing power plant is regulated by an engine thermostat, automatic

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radiator shutters and a thermostatically controlled fluid-coupled fan oprating at the following temperatures:

Thermostat opening	170°F to 180°F
Shutter opening	178°F to 185°F
Fan full RPM	188°F to 195°F
"Hot Engine" light and buzzer	216 ± 5°F

Engine temperature of 180°F minimum, 200°F maximum must be maintained between -35°F and +100°F ambient.

Existing radiator has 3 $^3/_4$ inch core thickness, 750 sq. in. frontal area, 8 $^1/_2$ fins per inch and is side facing at left rear corner of bus.

The cooling system must supply heat to the passenger compartment and driver area through an existing 15 GPM auxiliary pump mounted in the bus interior. Heater cores will require a maximum of 155 000 BTU/HR based on 100°F water-air temperature difference.

Material of construction of lines to cooling system defined -inlets, outlets of brass; fittings silver-soldered, or phospho-copper-welded in place, or 95%-5% tin antimony solder. Fittings in cooling system are brass or cast iron.

Water hose shall be Armet silicone hose or approved equal.

Hose clamps (stainless steel), double-acting Tridon, or equal.

Cooling system shall not interfere with low water detector and indicator lamp, or operation of pressure relief valves in cooling system.

Supplier to specify antifreeze level required for service, if any, (to overcome added cooling effect of vapourization of propane) under winter conditions.

1.4.5 Engine Interface to the Existing Transmission System

The engine shall be made compatible with the GM V730 Allison transmission system through the addition, if required, of an adapter. The need for an adapter shall be indicated by the manufacturer.

The engine manufacturer's specification shall indicate the anticipated performance of the engine/transmission system and performance difference (if any) at all gear ranges between that

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to be provided by the propane engine system over that of the standard diesel engine with the same Allison Transmission.

1.4.6 Engine Interface to Propane Storage Tank

Part 1 of the programme requires the supplier to provide the fuel storage tanks, valving and gauges and to provide instructions and assistance to OC Transpo staff to interface this system with the engine within the vehicle (item 1.1.3 to Technical Specification). A requirement of Part 1 is also to provide specifications, drawing and instructions to enable OC Transpo staff to purchase fuel tanks and fuel lines from two or more recommended vendors within N. American for interfacing with engines supplied under Part 2 of the supply contract.

The fuel storage tanks, supply lines and other in-vehicle equipment will conform to the regulations and standards established by the Fuels Supply Branch of the Ontario Ministry of Consumer and Commercial Relations and the installation practices, inspection procedures will also conform to the regulations administered by that authority, which are given in Attachment 2.

Further, the total engine/fuel system will be designed to enable the vehicles to conform to the regulations on parking and garaging of propane vehicles in Ontario, which are also given in Attachment 2 (particularly the Canadian Gas Association Codes B149.2).

1.4.7 Engine Dimensions

The propane engine dimensions shall be such that the engine and attachments can be placed within the existing engine envelope of the OC Transpo GM buses.

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ATTACHMENT 2 TO TECHNICAL SPECIFICATIONS

The Attachment forms part of Schedule I

2.0 SAFETY AND EMISSION STANDARDS

2.1 Safety Standards

In-vehicle safety standards for Ontario to be latest update from the Fuels Safety Branch of the Ministry of Consumer and Commercial Relations of the Province of Ontario. This currently corresponds to the Fuels Safety Branch Standard #1/81, "Installation of Propane Carburetion Equipment and Tanks on Over-the-Road Vehicles" and the National Standards of Canada CAN 1-B 149.2. "Installation Code for Propane Burning Appliances and Equipment" published by the Canadian Gas Association.

For tanks the applicable Ontario regulations are Regulation 75, revision 1970, Chapter 47 of the Boiler and Pressure Vessels Act 1962-63 (see the Attachment of the Technical Standard B51: "Code for the Construction and Inspection of Boilers and Pressures Vessels" published by the Canadian Standards Association.

For supply lines and fittings the following apply:

- ANSI Standard B16.3 "Malleable Iron Screwed Fittings", published by the American National Standards Institute.
- National Standards of CAN 1-8.3 "Thermoplastic Hose and Hose Couplings for Conducting Propane and Natural Gas.", published by the Canadian Gas Association, 55 Scarsdale Road, Don Mills, Ontario M3B 2R3
- National Standards of CAN 1-8.1 "Elastometric Hose and Hose Couplings for Conducting Propane and Natural Gas.", published by the Canadian Gas Association, 55 Scarsdale Road, Don Mills, Ontario M3B 2R3
- ANSI Standard B2.1 "Pipe Threads (Except Dryseal)", publishd by the American National Standards Institute.
- CSA Standard B63 "Welded and Seamless Steel Pipe", published by the Canadian Standards Association, 178 Rexdale Blvd., Rexdale, Ontario.

...A9

- ANSI Standards H 27.1 "Seamless Red Brass Pipe" (ASTM B43-80), published by the American National Standards Institute.
- ASTM A 539-79 "Electric-Resistance Welded Coil Steel Tubing for Gas and Oil Lines", published by te American Society for Testing and Materials.

The applicable standards are briefly described in the booklet "Switching to Propane - a Guide for Fleet Operators" issued in 1982 by the Ministry of Transport and Communications, Policy Planning and Research Division.

2.2 Applicable Vehicle Emission and Noise Standards (1982)

The engine emission levels shall correspond to current legislation in Canada which requires:

- Combined hydrocarbon and nitrogen oxide emissions not exceeding 16 grams/bhp.hr. and carbon monoxide emission levels not exceeding 40 grams/bhp.hr.
- The maximum level of noise emissions shall not exceed the values given in Attachment 1, item 1.4.2 (page A4).

APPENDIX H

DEMONSTRATION PROPOSAL

DEMONSTRATION OF PROPANE AS A FUEL IN URBAN BUSES

Submitted by:

J. Bonsall
General Manager,
Ottawa Carleton Regional
Transit Commission
1500 St. Laurent Blvd.,
Ottawa, Ont.

To:

Enerdemo Canada
Energy, Mines & Resources
Attention: Mr. Paul Belzile

and Ontario Ministry of Energy
Attention: Mr. G. Olah

c.c. Ontario Ministry of
Transportation & Communications
Attention: Mr. O. Colavincenzo

Energy, Mines & Resources
Attention: Mr. J. Heenan

5 March 1985

SUMMARY

The Ottawa-Carleton Regional Transit Commission (OC Transpo) will complete a program of research, planning and equipment acquisition by 31 March 1985 which will equip 15 city buses, a fuelling facility and a section of the St. Laurent garage for use of propane.

OC Transpo proposes to conduct a two-year demonstration of the use of the propane bus fleet in revenue service and of the fuel storage, fuelling and modified garage facilities in a program budgeted at $495,000. Financial support is sought by OC Transpo in the amount of $135,000 from the ENERDEMO program of the department of Energy, Mines and Resources Canada, and $135,000 from the Ontario Ministry of Energy. The funds will be used to support the demonstration and to generate technical and economic data on the propane system and their comparison with data on buses equipped with conventional engines and a new 4-cycle diesel-engine. The data will be made available in the form of reports, publications and other publicity releases. Seminars and liaison with other bus properties will enhance the information transfer process and provide a basis for decisions by OC Transpo and other bus properties on future large-scale use of propane in Canada's city bus fleets.

The principal benefits from a successful demonstration will be:

- a reduction in fuel costs of about $4,500 per bus per year
- displacement of 40,000 to 50,000 litres per year of diesel fuel by indigenous propane and
- reduced exhaust and noise emissions compared to the current diesel fuel-based system.

1. INTRODUCTION

The Ottawa-Carleton Regional Transit Commission (OC Transpo) proposes to undertake a two-year program of demonstration of the use of propane fuel in a fleet of 15 specially equipped city buses operated in revenue service during the period 1 April 1985 to 31 March 1987.

The demonstration will generate new operational, engineering and economic information on the performance of the propane city bus fleet which will be compared with the performance of conventional 2-cycle diesel-engined buses and the monitored performance of a 4-cycle diesel-engined bus.

The demonstration will include the monitoring of the fuel storage and propane fuelling facility installed by OC Transpo and of the special maintenance and garaging facilities and operations required for propane vehicles. In addition to the generation and publication of technical information, the demonstration program will include surveys of bus riders, bus drivers and other employees of the Commission to determine their response to the propane system. A further key element of the program will be the transfer of technology and economic information to other bus properties in Canada and the generation of information on the performance and acceptance of the propane fleet which will be suitable for publication by, or in support of, the federal government's ENERDEMO and other off-oil programs and programs to the same purpose conducted by the government of Ontario.

2. PRIOR WORK

The demonstration of buses in revenue service can now be undertaken because the preliminary research, planning and most of the facilities required have already been acquired under a preliminary program conducted by the Commission since November 1983, supported jointly by the Ontario Ministry of Energy, the federal department of Energy, Mines and Resources under the provisions of a CREDA agreement, and in part by OC Transpo funds. Valuable technical and management support provided by the Ontario Ministry of Transportation and Communications was also provided to the project. The expenditures for this research, planning and equipment acquisition activity are estimated to total $942,490 by the termination date 31 March 1985, contributed as follows:

EMR Canada	$401,220
MOE Ontario	401,220
OC Transpo	140,050
Total Expenditure	942,490

The preliminary work is to be fully described in a 31 March 1985 final report on the CREDA project. The major accomplishments to date of the preliminary program include:

(a) Research and Related Development Activities

1. The selection of an appropriate propane engine and its re-engineering to interface with the unique GM transmission system which will be retained in the converted buses.
2. The integration of the new engine with the engine envelope, drive train, controls and other sub-systems in the bus.
3. The design, installation and testing of a new manifolded propane fuel tank system in the bus.
4. Dynamometer, track and road testing of the propane bus (including

comparison with existing GM diesel buses) to previously established performance-acceptance specifications which established the performance, fuel consumption and preliminary safety performance of the converted bus.

5. Comparative dynamometer testing of the Dereco (FIAT) propane engine and the corresponding FIAT 4-cycle diesel engine and comparison with the standard GM 2-cycle engine.
6. The selection of fuel suppliers, the design of the on-site fuelling facility and preparation of a safety manual.
7. Training of OC Transpo staff for propane vehicle conversions, maintenance and inspection according to the safety requirements of the Ontario Ministry of Consumer and Corporate Relations.

(b) Acquisition and Start Up Activities

8. Conversion of a series of buses to propane which will result in 15 propane and one 4-cycle diesel-engined buses in operation on or about 1 April 1985.
9. Installation of a fuel storage and refuelling facility at the St. Laurent Blvd. site and training of fuellers.
10. Definition of the changes needed within the garage to permit safe parking, maintenance and repair of the propane buses when in regular service, and installation of a part of the test and safety equipment required.
11. Operation of a limited number of propane buses within the system to test compatibility with the fleet and to gain initial public and driver acceptance of the propane buses. At completion of this preliminary testing about 175 shifts of operation of the propane fleet will have been accomplished.
12. Training of the maintenance staff by installation, testing, repair and rework of the propane engines occasioned by the preliminary nature (semi-commercial status) of the engine manufacturing technology.

3. THE PROPOSED 1985-1987 DEMONSTRATION

The experimental and start-up phase permits the initiation of the required in-revenue service operation of the propane fleet from 1 April 1985 and operation of a sufficient number of the buses within the established system to obtain reliable data on their performance, economics and acceptance over all routes and under all weather, traffic and load conditions.

The major tasks to be undertaken in the two year demonstration period are summarized in Exhibit 1 and described as follows:

The conversion 15 propane buses and the 4-cycle diesel-engined bus will be completed, inspected and the status and performance of the converted fleet thoroughly characterized and documented. The thorough analysis of the vehicles (engines, fuel tanks and lines, transmission coupling, tires) will be repeated after one year in service and at the completion of the demonstration.

Similar levels of testing and inspection will be made with the bulk fuel storage and vehicle refuelling facility. It is apparent that the vehicle refuelling equipment now available can be improved to provide automatic fuel cut-off to the bus when the tank is filled to the level prescribed (80% level to provide for fuel expansion is a legislated safety requirement) and a faster fuelling cycle. Various types of equipment are available for investigation and incorporation into the OC Transpo system installed by Superior Propane, but a development-test activity is scheduled and budgeted. A two point filling fuel tank will be installed on one bus and tested.

The garage revisions and equipment acquisitions that have been undertaken in the preliminary program to provide sensing of propane leaks, increased ventilation and flame-proofing of selected equipment (space heaters, electric motors, lights) will be extended to accommodate the 15 bus fleet and to further improve the safety and logistics of bus garaging, inspection and repair.

The key rationale for the adoption of propane as a city bus fuel is the reduction in fuel costs. Tests on the first propane engine indicated that fuel savings amounting to about $4,500/bus/year will be available to OC Transpo from the conversion from diesel to propane at present price levels, despite the high volumetric consumption of propane (about 1.7 volumes) relative to diesel fuel (1 volume). The fuel consumption of the propane buses and the 4-cycle diesel bus will be monitored, and the engine manufacturer's suggestions and frequent tune-ups will be used to improve the fuel economy.

A second key rationale for the adoption of propane buses is their potential for reducing environmental pollution in terms of noise, particulates and noxious exhaust emissions (NOx and carbon monoxide in particular). Although environmentally superior to the diesel engine, new standards are expected to be introduced in the demonstration period. The emerging legislation will be monitored and recommendations made to OC Transpo to facilitate future fleet compliance.

The training of drivers, fuellers and certification of propane engine maintenance and inspection staff will be continued to maintain a team of 30-40 propane trained staff: supporting training programs and safety aids will be developed.

The demonstration program is designed to generate quantitative technical and economic information on the propane system and other information on the attitudes of the public and bus property staff that may affect continued and expanded use of propane buses. The development of the required technical and economic information will be aided by the use and improvement of a computer-based, project-specific data acquisition analysis and reporting system now under development at OC Transpo. Attitudinal information will be generated from interviews, on-going criticisms of the project and from rider and driver surveys, part of which may be contracted out to specialist survey organizations. A technical consultant or consultants will be retained to advise the Steering Committee and the Project Manager on the project and developments in alternative and conventional fuels for buses, to conduct special investigations as required, and to prepare project reports, technical papers, seminars and to advise on the technical content of publicity material.

4. BUDGET AND FINANCING

The budget required for the project totals $495,000. It is suggested that OC Transpo will contribute $225,000, the federal department of Energy, Mines and Resources $135,000 under the terms of the ENERDEMO program, and the Ontario Ministry of Energy $135,000, with disbursements as given in Exhibit 2.

The Ottawa-Carleton Regional Transit Commission has already approved the $225,000 contribution. It is understood that the federal government contribution under the ENERDEMO program is conditional upon agreement being reached with the Ontario Ministry of Energy concerning their matched financial contribution, and technical and management support to the program which will be available from the Ontario Ministry of Transportation and Communications.

Within this budget framework of cost sharing by the government of Canada and the government of Ontario, OC Transpo will enter into separate agreements with EMR and the Ontario ministries and will bill EMR and Ontario directly and separately for their share of the budgeted expenses not assumed by OC Transpo. Major expenditures, commitments or changes in the program which will result in charges to the EMR and Ontario project budgets will be described in written work statements and subject to consensus approval sought at Steering Committee meetings, or through special meetings and other means of joint consultation. Examples of this include: committee review of a proposal to develop and/or test and install an improved fuel monitoring and control system; review of the technical consulting component of the information and technology transfer activity.

5. ORGANIZATION FOR THE PROJECT

5.1 Contracts

OC Transpo will execute two contracts with EMR Canada's ENERDEMO office and with the Ontario Ministry of Transportation and Communications. The contracts will have essentially identical terms of reference and each will be funded at the same $135,000 level. The contracts contain the provision that the EMR participation and contribution are dependent upon the striking of the contract between OC Transpo and the Ontario Ministry of Transportation and Communications. It is understood that the Ontario Ministry of Transportation and Communications may obtain its funding for the contract from the Ontario Ministry of Energy.

6. PROJECT POLICY AND MANAGEMENT (see Exhibit 3)

The key policy making and management group for the demonstration will be the Steering Committee whose membership will include representatives of OC Transpo, the Ontario Ministry of Energy, the Ontario Ministry of Transportation and Communications, the ENERDEMO Program Office of EMR Canada, and a representative of the Transportation Energy Division, EMR Canada. The OC Transpo Project Manager will bring to bear all the required resources of OC Transpo, manage the activities of consultants and contractors, and be responsible to the Steering Committee for production of quarterly progress reports, special technical reports and the final report.

MTC has offered to act as project monitor. This has been a satisfactory arrangement in the current research phase and has strengthened the program through provision of technical advice and support.

7. PROGRAM OUTPUT

The program will generate the following output:

1. Technical Reports and a Final Report providing statistically valid information on the operating experience, capital expenditures and costs of operating:
   a. the 15 propane bus fleet and
   b. the 4-cycle diesel-engined bus, both compared to the conventional GM 2-cycle diesel buses operated by OC Transpo over the demonstration period
   c. the propane fuel storage and fuelling facility
   d. the special in-garage facilities needed to safely operate the propane bus fleet.
2. A Survey Report (to be included in the Final Report) providing data on the attitudes of the riding and other publics to the propane system.
3. Publications in reputable transportation, transit and technical publications and others which will be of value to transit bus operators in Canada.
4. Publicity in the form of articles, seminars, displays.
5. A series of Interim Technical Reports and Special Reports dealing with project progress and special technical/economic/safety and other issues related to propane use in transit applications.
6. Guidelines for use by OC Transpo in its determination of the merits of continuing and expanding propane use which will be valuable to other properties.

8. PROGRAM BENEFITS

8.1. Cost Savings

The preliminary tests conducted with the prototype propane bus at OC Transpo showed that under the present contracts for supply of propane and diesel fuel OC Transpo is expected to save the equivalent of 9¢/litre diesel fuel (about 20% of fuel cost) by use of propane, providing an average annual fuel cost saving of $4,500 for each bus in active service.

The cost of maintenance and other supplies (such as spark plugs) for the propane buses is unknown, but experience outside OC Transpo indicates savings and added costs in revenue service operations, including maintenance, are not expected to differ greatly between the propane and diesel buses. In the OC Transpo case added cost is incurred in the conversion of buses to propane through addition of the fuel tanks and controls (about $4,000/bus). The exchange of the propane engine for the diesel engine is not an added expense (diesels are regularly replaced or cannibalized).

The payout from conversion of existing buses, excluding garage changes, is therefore substantial. Over the remaining life of a converted bus the net operating cost savings are expected to total about $58,500.

After allowance for the conversion of the garage to accommodate propane, which has been initiated at an estimated total cost of $245,000, the 15 propane buses operated over the remaining years of their life will show a large cost saving ($632,500 total or $42,166/bus or $3,000/bus/year on average).

In Ontario, new buses purchased to use propane are not subject to the provincial sales tax. If this policy continues, the lifetime savings per bus would include a tax saving of about $13,000, providing a life-cycle cost saving (after allowances for garage conversions) of about $73,000, over the anticipated 800,000 kilometer service life of the bus, or an anuual saving of $3,650/bus. Should 50% of the Commission's 780 buses be propane-fuelled in the future, the annual savings under the above conditions would be $1,423,500.

The demonstration could provide an example to other properties. Assuming this would lead to 10% penetration of Canada's 12,850 city bus population, some 51 million litres of diesel fuel would be displaced and fuel cost savings from low cost propane could exceed $3.2 million/year (at a 15% discount on a diesel fuel price of 42¢/litre). It is anticipated that the gap between the price of diesel fuel and the price of propane will widen in the future and that increased benefits from propane conversion will be realized. A summary of the cost effects is given in Exhibit 4.

8.2 Improvements in the Environment

The propane engine currently used by OC Transpo has a lower level of undesirable exhaust gas components and is significantly quieter than the current diesel engine. The program will seek to measure these environmental benefits which cannot be quantified in dollar terms, but will contribute to the public acceptance of the propane bus and perhaps an increase in future ridership levels. OC Transpo anticipates substantial expense will be incurred in the future to improve the environmental performance of diesel-engined city buses. The expense will likely be in the added cost of buses equipped for low particulate, NOx and carbon monoxide emissions and perhaps an increase in fuel costs if specially selected (high cetane) diesel fuel is required to reduce pollution.

8.3 Security of Fuel Supply/Oil Savings

There are indications that Canada's demand for diesel fuel (and particularly the #1 diesel fuel quality) will grow in the future at a time when Canada will still be dependent on imports of the light crude oil needed to produce it. The potential for shortages and future increases in the cost of diesel fuel therefore exist and the choice of propane as an alternative fuel will diversify the Commission's fuel requirement and reduce the risk of supply curtailments and cost increases. In addition, the conversion to propane will replace imported oil by indigenously-produced propane that is currently in substantial surplus supply and under price pressure in export markets. About 40% of Canada's 160,000 barrels/day production of propane is surplus to Canadian needs and the export realization at the Alberta border is frequently below 10¢/litre (the NEB has set a new minimum export price of about 8.3¢/litre recently).

8.4 Industrial Development Opportunity

Although the propane engines acquired by OC Transpo were imported, it is expected that successful demonstration of propane engines could lead to an industrial opportunity through assembly, or at minimum, conversion of engines in Canada. The fuel tanks, lines and controls used are of Canadian design and represent a growth opportunity for the Canadian producers.

Exhibit 1: PROPANE BUS DEMONSTRATION SCHEDULE OC TRANSPO

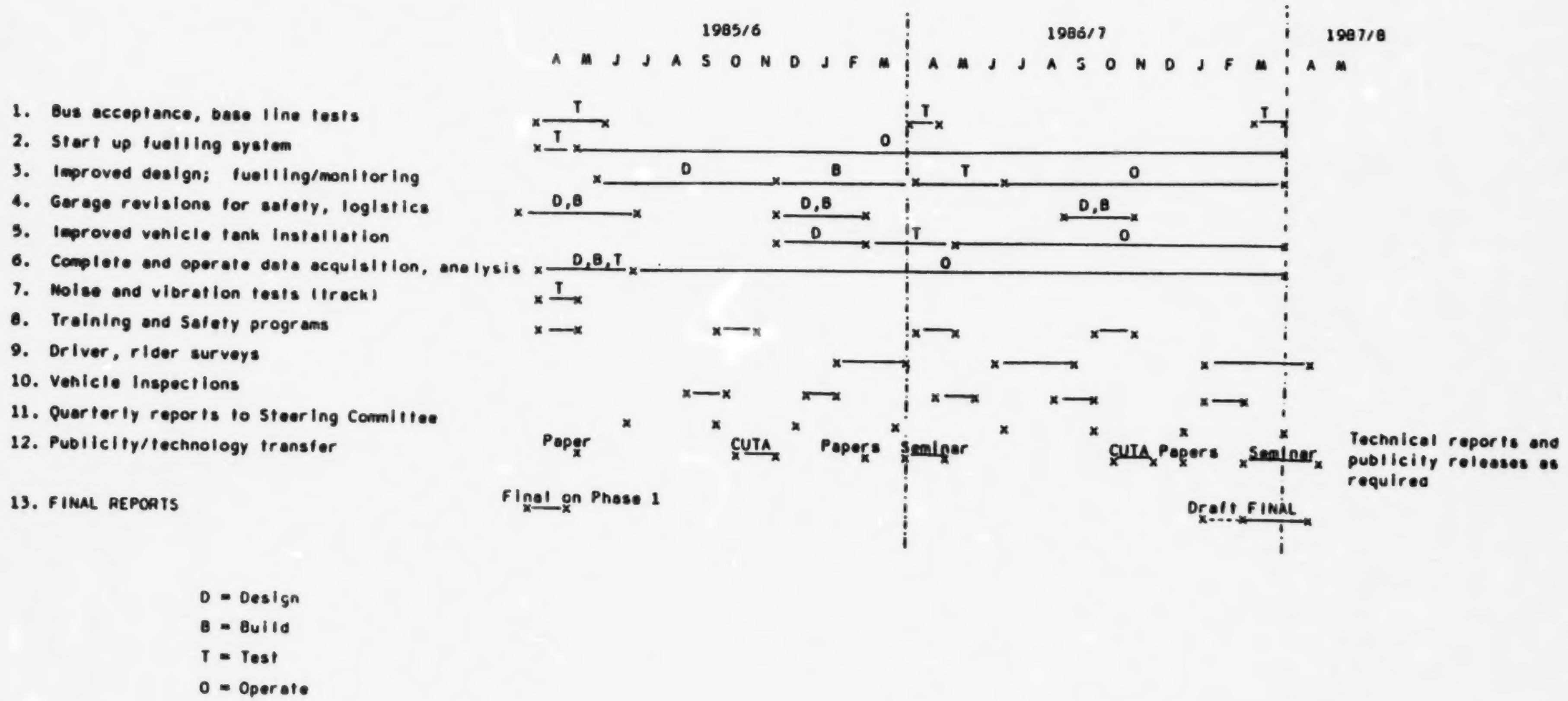


Exhibit 2: PROPANE BUS DEMONSTRATION BUDGET AND CASH FLOW

(Thousands of Dollars)

	1985/6			1986/7			1987/8			PROJECT TOTAL		
	EMR/MOE	OCT	TOTAL	EMR/MOE	OCT	TOTAL	EMR/MOE	OCT	TOTAL	EMR/MOE	OCT	TOTAL
1. Bus acceptance, inspections, increased maintenance	-	14	14	-	12	12	-	-	-	-	26	26
2. Fuel station tank farm tests, increased operating costs	-	11	11	-	9	9	-	-	-	-	20	20
3. Garage revisions for safety, logistics	32	-	32	3	-	3	-	-	-	35	-	35
4. Training, safety programs	-	3	3	-	3	3	-	-	-	-	6	6
5. Improved fuel tank	8	-	8	-	-	-	-	-	-	8	-	8
6. New fuelling, monitoring system	45	-	45	15	-	15	-	-	-	60	-	60
7. Vehicle technical service Dereco	12	-	12	6	-	6	-	-	-	18	-	18
8. Technical consulting	30	-	30	30	-	30	8	-	8	68	-	68
9. Public and driver surveys	-	4	4	20	4	24	2	-	-	22	8	30
10. Data acquisition, analysis	-	32	32	-	32	32	-	5	5	-	69	69
11. Publicity	16	-	16	18	-	18	5	-	5	39	-	39
12. Engineering, project administration	-	45	45	-	45	45	-	6	6	-	96	96
13. Travel	10	-	10	8	-	8	2	-	2	20	-	20
TOTAL	153	109	262	100	155	205	17	11	28	270	225	495

Revised 5.3.85

Exhibit 3: ORGANIZATION FOR PROPANE DEMONSTRATION

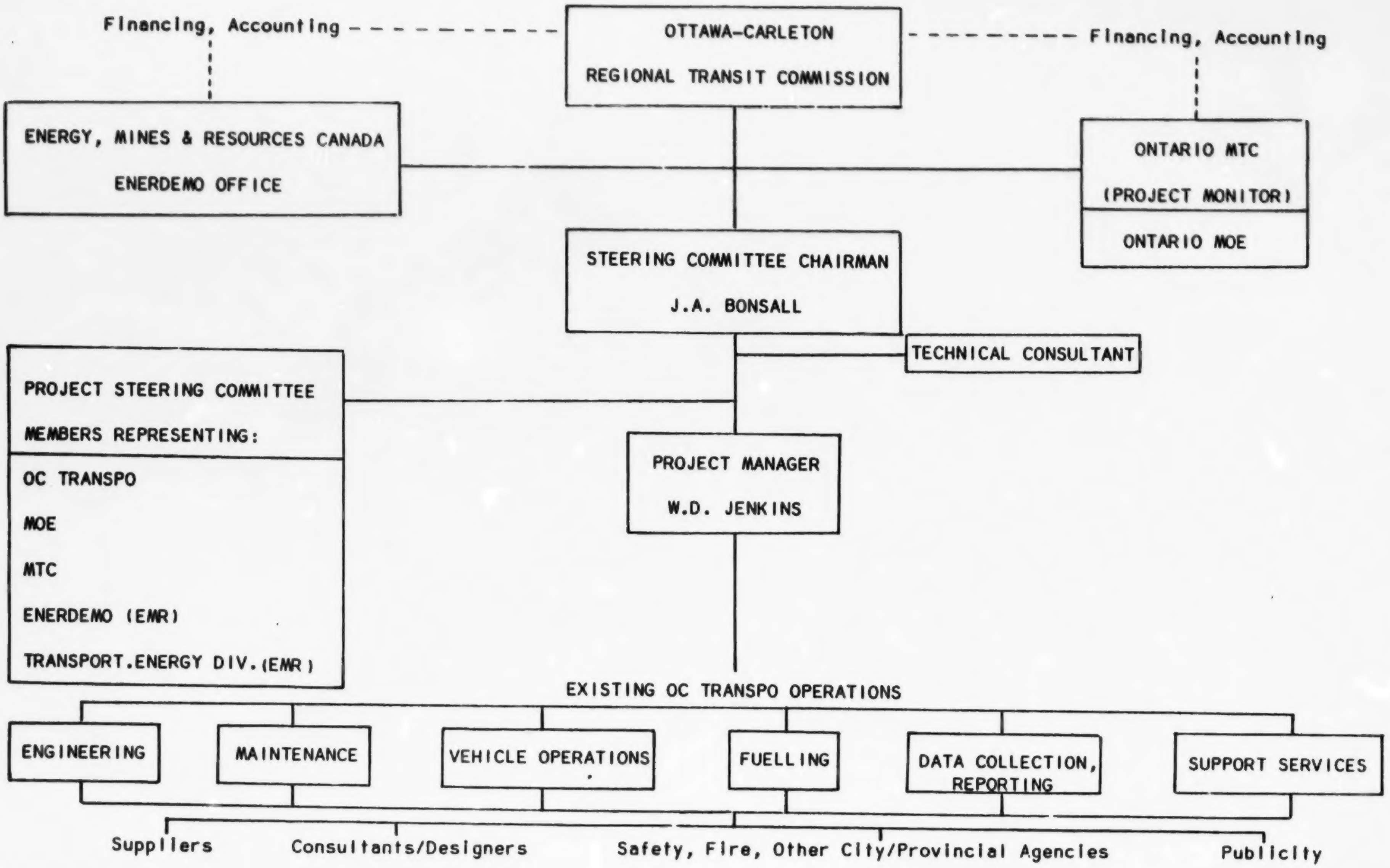
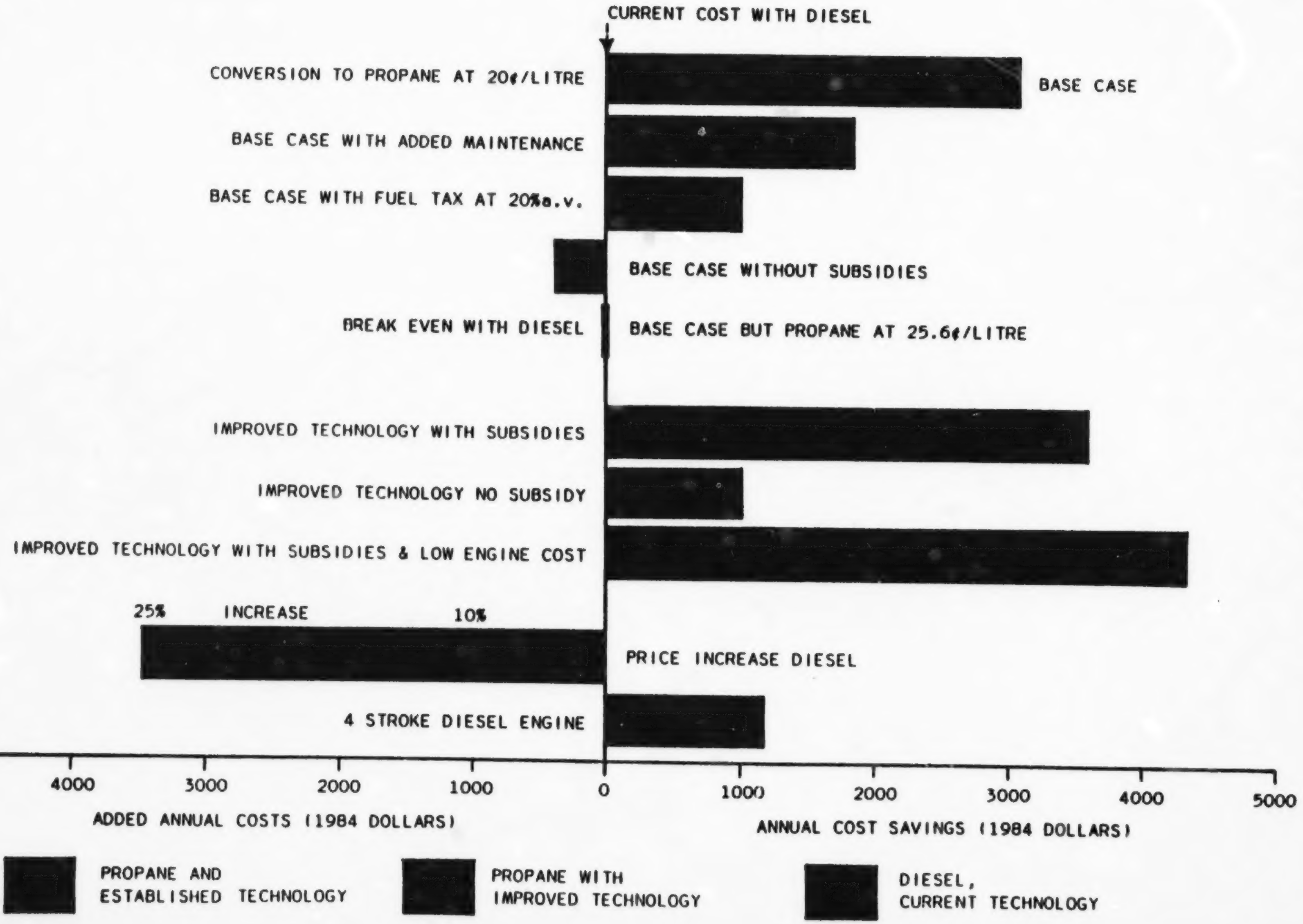

Financing, Accounting
OTTAWA-CARLETON
REGIONAL TRANSIT COMMISSION
Financing, Accounting
ENERGY, MINES & RESOURCES CANADA
ENERDEMO OFFICE
ONTARIO MTC
(PROJECT MONITOR)
ONTARIO MOE
STEERING COMMITTEE CHAIRMAN
J.A. BONSALL
TECHNICAL CONSULTANT
PROJECT STEERING COMMITTEE
MEMBERS REPRESENTING:
OC TRANSPO
MOE
MTC
ENERDEMO (EMR)
TRANSPORT.ENERGY DIV.(EMR)
PROJECT MANAGER
W.D. JENKINS
EXISTING OC TRANSPO OPERATIONS
ENGINEERING
MAINTENANCE
VEHICLE OPERATIONS
FUELLING
DATA COLLECTION, REPORTING
SUPPORT SERVICES
Suppliers
Consultants/Designers
Safety, Fire, Other City/Provincial Agencies
Publicity

Exhibit 4: CHANGES IN ANNUAL COST WITH PROPANE AND DIESEL BUSES


CURRENT COST WITH DIESEL
CONVERSION TO PROPANE AT 20¢/LITRE
BASE CASE
BASE CASE WITH ADDED MAINTENANCE
BASE CASE WITH FUEL TAX AT 20%a.v.
BASE CASE WITHOUT SUBSIDIES
BREAK EVEN WITH DIESEL
BASE CASE BUT PROPANE AT 25.6¢/LITRE
IMPROVED TECHNOLOGY WITH SUBSIDIES
IMPROVED TECHNOLOGY NO SUBSIDY
IMPROVED TECHNOLOGY WITH SUBSIDIES & LOW ENGINE COST
25%
INCREASE
10%
PRICE INCREASE DIESEL
4 STROKE DIESEL ENGINE
5000
4000
3000
2000
1000
0
1000
2000
3000
4000
5000
ADDED ANNUAL COSTS (1984 DOLLARS)
ANNUAL COST SAVINGS (1984 DOLLARS)
PROPANE AND ESTABLISHED TECHNOLOGY
PROPANE WITH IMPROVED TECHNOLOGY
DIESEL, CURRENT TECHNOLOGY